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FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

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Mining and Metallurgical Section.

(Stated Meeting, held Thursday, March 9, 1905.)

Tonopah Mining District.

By J. E. Spurr, U. S. Geological Survey.

[The Tonopah mining district is one of the fresh discoveries of rich ores of gold and silver in the west. The geology of the region is extremely complicated and there are many features of especial scientific and practical interest. In very few mining districts is the discovery and proper development of the ores so dependent upon a knowledge of the principles of economic geology. The author of this paper has spent the larger part of several years studying the district, and some of the most interesting results are outlined below.—THE EDITOR.]

The mining district of Tonopah, in Western Nevada, has attracted much attention among mining men during the last few years, on account of the considerable quantity and rich character of its gold-silver ores. This district lies in an arid region, which, although formerly considerably explored and exploited by miners, had, for a long time previous to the discovery of

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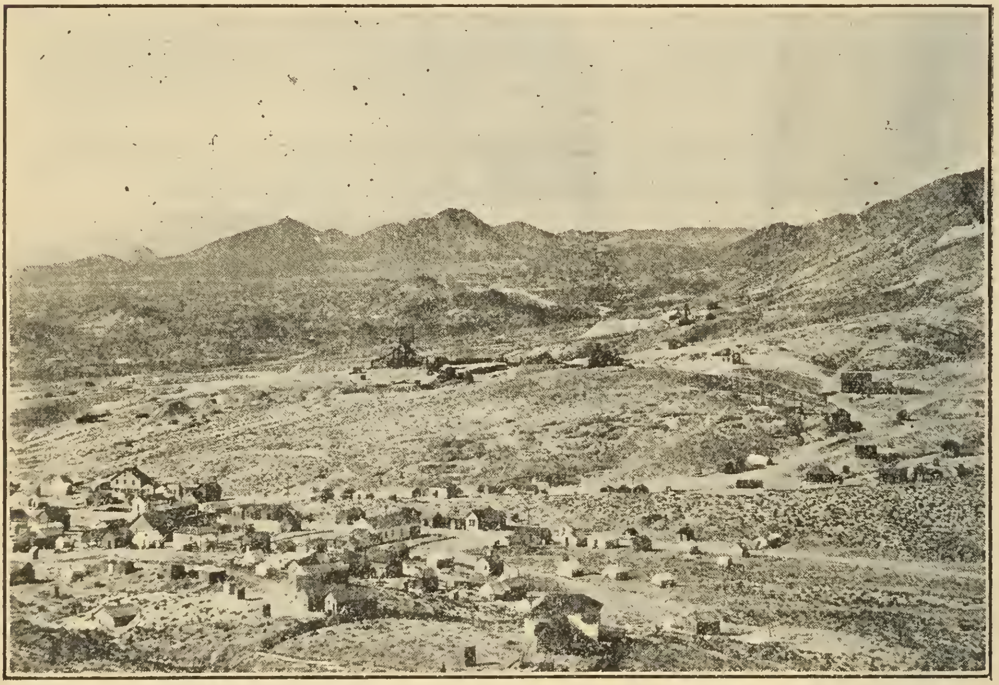
this camp, been practically abandoned. Within this same region lie the famous camps of Virginia City and Eureka, which twenty or thirty years ago were very heavy producers, but which have gradually dwindled more and more in importance. Numerous other camps were, in those old ways, scattered thoughout this desert country, such as Silver Peak, Hot Creek, Tybo, Reveille, Candelaria, and many others, but most of these had become nearly or quite deserted.

A preliminary event which is directly responsible for the discovery of Tonopah was the location of a small camp, called



Tonopah.

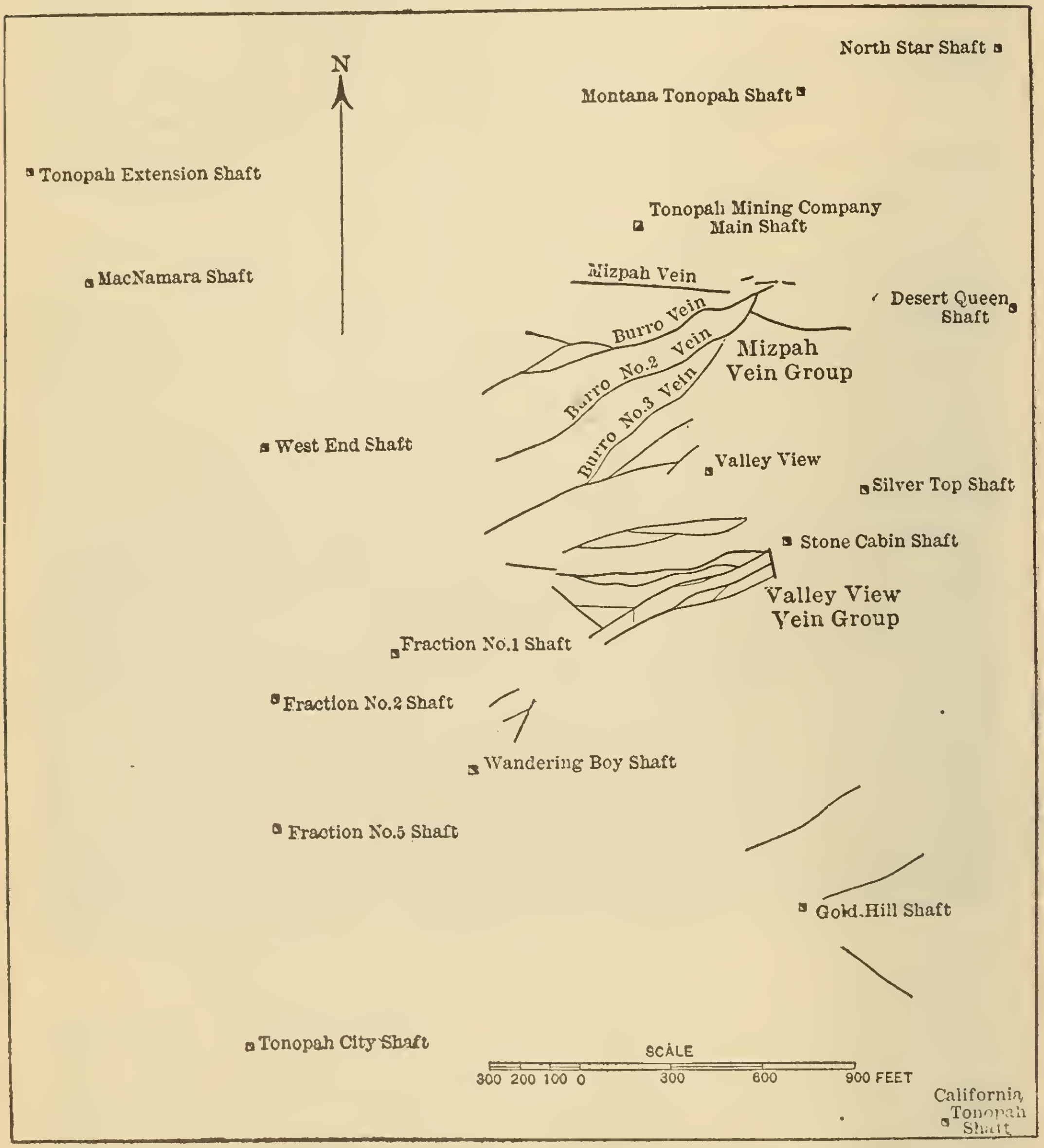
the Southern Klondike, some ten miles south of the present Tonopah. This was located a short time previous to my first trip, by ranchers who visited the locality in connection with their sheep herding. This district has never attained any importance, although some ore has been taken from it. In traveling from his home, in Belmont, the county seat of Nye County, to the Klondike camp, James L. Butler collected specimens from the veins outcropping on what is now called Mizpah Hill, at Tonopah, and thus led to the discovery of this now famous camp. The properties that Mr. Butler located

were at first worked by him on the leasing system, and afterwards disposed of to the Tonopah Mining Company, the stock of which is chiefly held in Philadelphia. The group owned by this company on Mizpah Hill comprises the Mizpah and Valley View veins, which are the chief outcropping lodes. Subsequently it was discovered that the veins might be covered up by later volcanic rocks, and following up this information, shafts were sunk at random, some of which succeeded in finding rich veins of the same class as those just mentioned. The Montana Tonopah, Tonopah Extension, Fraction, and others, are among those which were thus successful. A camp of this sort was evidently a rich field for the mining speculator and promotor, for it was not necessary to have even a showing of ore to have a possible mine, so that the region for a long distance round about was soon staked and came upon the investment market. Up to the present time, however, there have been no veins of importance developed more than a short distance away from the original discoveries. The whole of this district in which ore has been found in paying quantities can easily be included within a circle three-quarters of a mile in diameter. At the present time the important producing mines, besides those of the Tonopah Mining Company, are the Montana Tonopah and the Tonopah Extension, and also the properties of the Tonopah Belmont Company.

In the Tonopah district more than in any other region that has ever come under my observation, the details of geology are connected in a most intimate way with the value and prospects of the mines. Therefore, I shall briefly sketch the general geology of the immediately contiguous region before mentioning in any detailed way the mineral-bearing veins.

Like the Comstock lode, the Tonopah veins lie in a district made up almost entirely of volcanic rock of Tertiary age. The actual date of these volcanics has been determined as Neocene, reaching from the early part of the Miocene down well into the Pliocene. The Tertiary volcanic activities began somewhat before the earliest period mentioned and continued after the latest manifestation which we have at Tonopah. At the neighboring camp of Silver Peak, sixty miles west of Tonopah, there is a basalt crater which can hardly be more than a few hundred years old.

The earliest of the volcanics at Tonopah, and the one with which the principal ore deposits are most closely connected, was an andesite, which I have called the earlier andesite, to distinguish it from a subsequent erupted rock of very nearly simi-

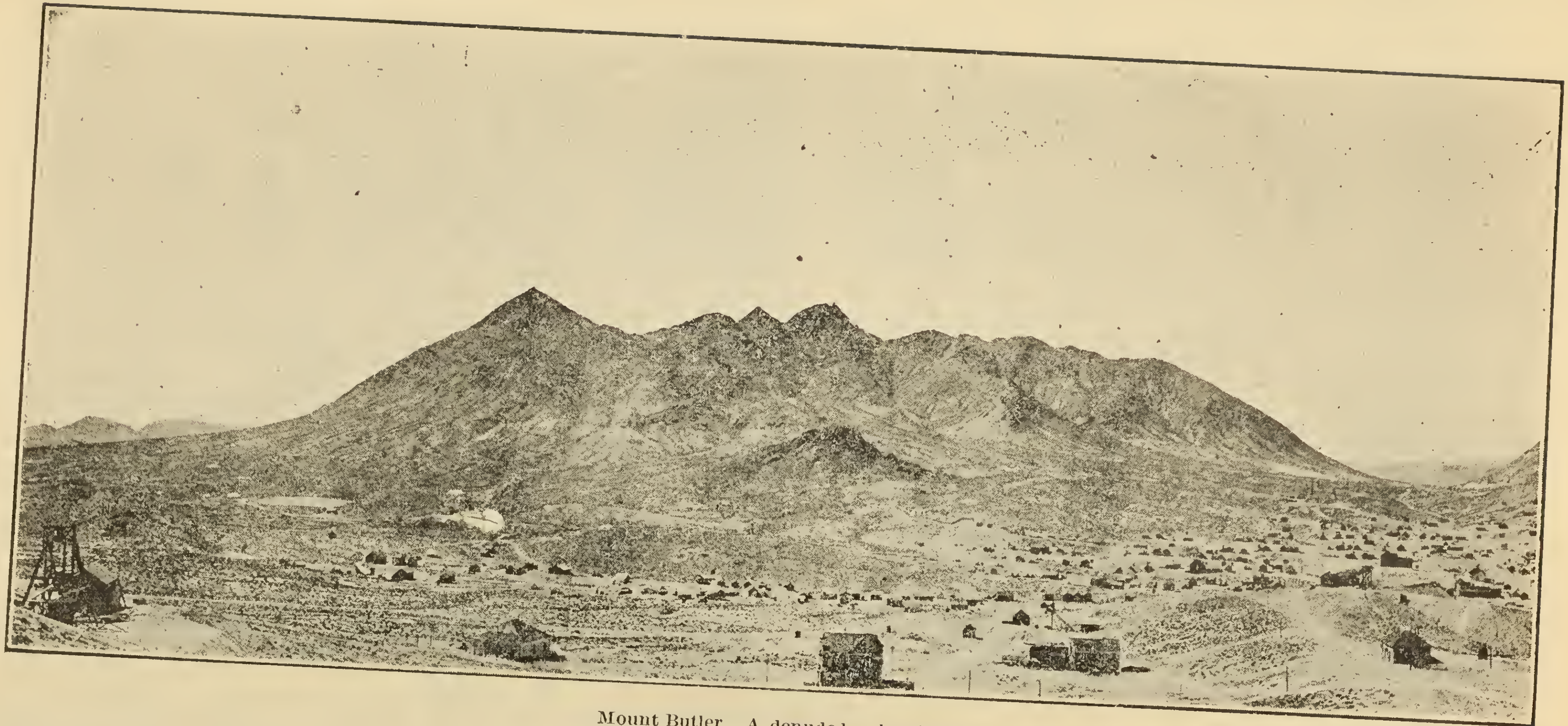


Map showing outcropping veins at Tonopah

lar composition. In the camp it is often called the lode prophyry, since in it the most valuable veins lie. The later andesite succeeded the earlier andesite after an interval. Subsequently the continuation of the volcanic activity is attested by a series of rhyolites and dacites. These rocks are very

closely connected in every way, chemically, mineralogically, in point of distribution, and in manner and time of eruption. They were, however, erupted at different periods and constitute distinct formations. These divisions I have variously denominated the Heller dacite, the Fraction dacite breccia, the Tonopah rhyolite-dacite, the Oddie rhyolite, and the Brougher dacite. These rhyolite-dacite formations consist of flows, tuffs due to showers of material from volcanic eruptions, and of injections into older rocks. The Fraction dacite breccia and that part of the Tonopah rhyolite-dacite area which lies south of Tonopah, in particular, consist of great masses of fragmental volcanic material. Among the latter rhyolite-dacite formations are the Brougher dacite and the Oddie rhyolite, which constitute the isolated hills around Tonopah. These hills represent the necks of Tertiary volcanoes, or the liquid lava which cooled in the throats of the volcanoes, whose main mass was made up of cinders and ash, now almost entirely swept away by erosion.

An incident in the geological history which broke the monotony of the repeated volcanic eruptions, was the formation of a great lake basin, and the deposition in it of a great thickness of stratified materials worn from the volcanic shores and carried out to settle in its depths. These deposits form the white stratified tuffs, beautifully bedded and well assorted, which are a conspicuous feature of the geology near Tonopah. Since these characteristics persist for thicknesses of several hundred feet, it is plain that the sediments were laid down in a body of standing water of considerable size and duration; and that this body was a lake is indicated by numerous general considerations and by the presence of fresh water infusoria in some of the strata. This lake must have been deep and of such an extent as to make it a very important geographic feature, so that the area around Tonopah must represent only a very small fraction of its whole extent. It came into existence at the close of the most active period of the Tonopah rhyolite-dacite eruptions. The formation of the lake was due to a depression of the crust, forming an enclosed basin, and I look with favor upon the hypothesis that this depression represents a collapse of the crust consequent upon the outpouring of so great a bulk of lava, gas and steam. I have proved that a similar



Mount Butler. A denuded volcanic neck.

subsidence, due beyond question to this cause, followed upon the eruption of the dacite and rhyolite volcanoes which are now represented by the volcanic necks already referred to. This lake basin, in this area at least, was terminated by an uplift of the crust, accompanied by a regional tilting. The area remained for a short time a quiet land surface, but soon there was an explosive eruption of basalt, followed by a thin flow of the same material. The formation of the dacite volcanoes, represented by the present hills, followed almost immediately upon this basaltic eruption. In connection with this last dacitic outburst there was a phenomenon of great importance, both to the scientist and to the miner, namely the faulting. I have shown that the principal faulting followed directly upon the formation of these dacitic cones. I have also shown that the area occupied by this dacite, which I have called the Brougher dacite, is coextensive with the region of observed complicated faulting. This complexly faulted region, which makes up the southern half of the small area which I have mapped,* is also down-sunken in comparison with the little-faulted region further north. Near the dacite necks the observed faults are rather more numerous than elsewhere, and in many instances it may be established that the blocks adjacent in the dacite have sunk down in reference to blocks farther away. From these intrusive necks the faults run in a roughly radial fashion, and seem to follow no regular system or trend. Detailed study of the contact phenomena of the dacite shows that the minute faults in the tuffs at these points generally have their downthrown side next the dacite.

From these facts I have reached the following conclusions. The faulting was chiefly initiated by the intrusion of the massive dacite necks. After this intrusion and subsequent eruption there was a collapse and sinking of the various vents. The still viscous lava sank, dragging downward with it the adjacent blocks of the intruded rock, accentuating the faults, and causing the described phenomena of downfaulting in the vicinity of the dacite.

The observations made upon faulting in this district are of extraordinary interest, for in this case the origin, time and

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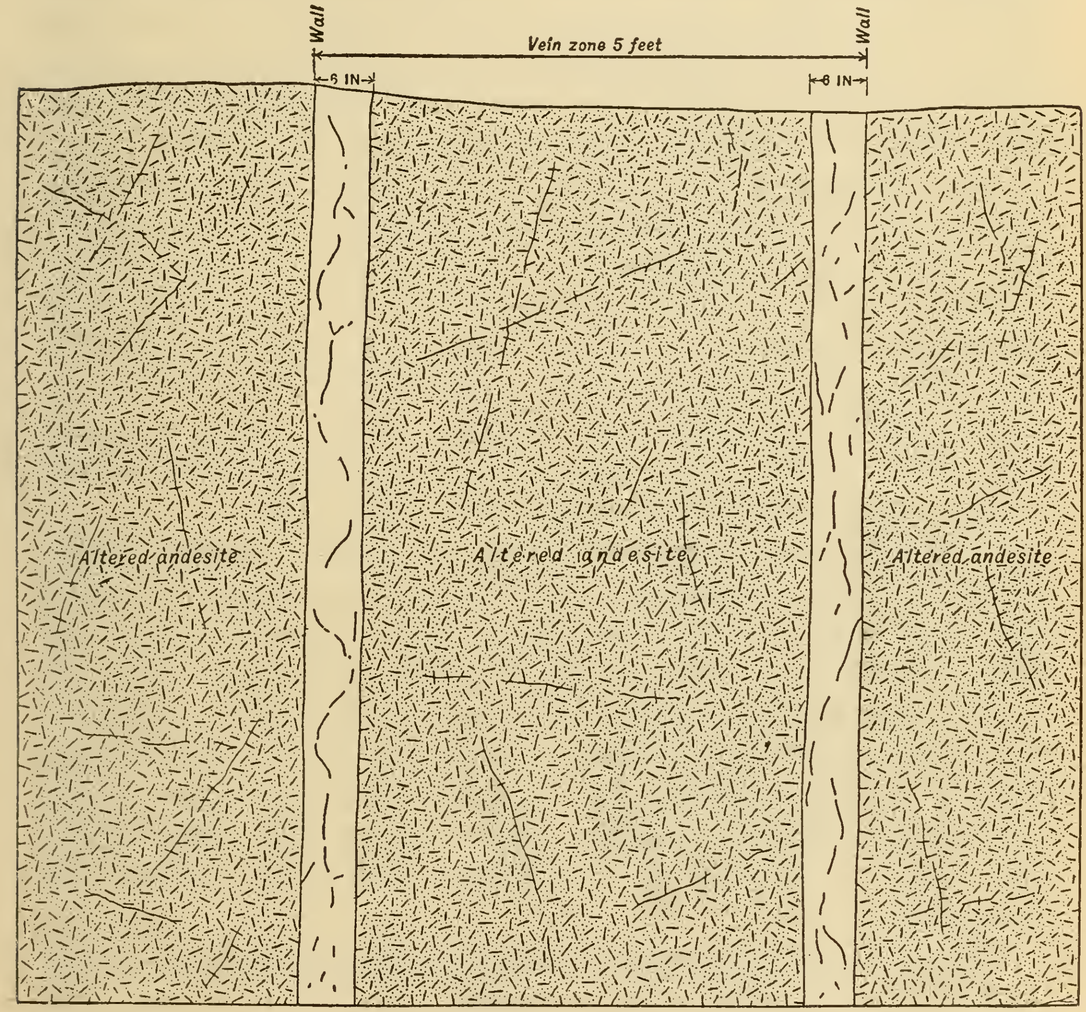
*Professional Paper No. 42, U. S. Geological Survey.

cause of the faulting are clearly understood. It is rare that any explanation other than a general unsubstantiated hypothesis can be applied to any particular case of faulting, but here it is plain that the faulting was the result of adjustments of the crust to suit violent migration of volcanic rock, that it originated with the swelling up of the crust and its forcible thrusting up and aside to make way for the numerous columns of escaping lava, and that it was continued after the cessation of the eruptions by the irregular sinking of the crust into the unsolid deposits from which the lava had been ejected. It can readily be seen that all sorts of pressure—from below upward, lateral, and downward by virtue of gravity,—must have been concerned in such movements; moreover, that the first faults were due rather to upward and lateral irregular shoves, while the latter ones, in many cases along the same planes as the first, were due to gravity. Thus reversed or normal faults are equally natural and both occur frequently. I will refer in detail later on to some special cases of faulting, after having described the mineral veins.

The veins in the earlier andesite at Tonopah have the regular extent, strike and dip characteristic of true veins. I have found out, however, by studying them, that they are not the fillings of open cavities, but rather that they have formed along zones, of maximum sheeting, these zones being from 3 to 8 feet wide, and having a regular strike and dip. For this reason I have announced that the veins were not true fissure veins, but were chiefly due to replacement. It is only fair to state, however, that the definition of a fissure vein is not universally agreed upon, so that veins having the origin which I have described would still be called fissure veins by some prominent geologists. Personally, I limit the term to veins which have filled open fissures, but by some the term is extended to any vein which is formed along what they denominate a fractured or fissured zone, even if it has formed by replacement of the rocks of this zone. The chief set of fractures along which the veins were formed extended in an east and west direction, and along zones which attain the maximum thickness of several feet, the close-set parallel fractures were especially abundant. These became the chief channels of circulation. In places the circulating waters divided into sepa-

rate channels, which diverged and frequently re-united, and often a lateral channel was found, of a character favorable to the egress of the water. Along these branch veins were formed. These channels, however, were apt to grow poorer as the distance from the main fracture zone increased, and these characteristics have been inherited by the veins which formed along them. The circulation channel now occupied by the Mizpah



Detailed vertical section of one of minor Valley View veins at surface.

vein may be taken as typical of the main fracture zone, and the diverging Burro veins, dwindling as they increase their distance from the master vein, as representing the lateral channels. The splitting and re-uniting is shown by the structure of the veins at many points.

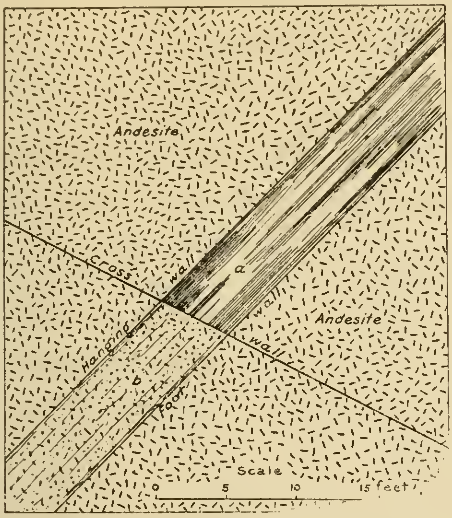
The fact that the circulation channel was a fracture zone and

not an open fissure is shown by a study of the veins, revealing all stages in the change from a fracture zone in andesite to a solid quartz vein. In many cases the vein consists simply of a zone of more or less altered andesite, not essentially different, except for a somewhat greater silicification, from the andesite which forms the walls. This zone is cut by parallel fractures having the same strike and dip as the walls, and the walls themselves are nothing more than stronger fractures of the same kind. In the next stage, where part of this fractured zone becomes altered to quartz, the main wall fractures have often been the most favorable for water circulation, so that sometimes a hanging-wall streak of quartz and a foot-wall streak are found, with only altered andesite between them. Sometimes also, either the hanging-wall or the foot-wall streak may be wanting. Next streaks of quartz parallel with the walls may be found, or the quartz may form a network with the andesite. Thus the process may be traced to the stage where the whole of the andesite is replaced by quartz, forming a solid vein several feet in width. As a rule, however, there is more or less of decomposed andesite forming part of the vein.

As exceptions there are streaks of quartz, usually small, within the vein, which show crustification and comb structure, and thus bear evidence of having been formed in cavities. Many of these cavities are of irregular shape and were not fissures, properly speaking, but spaces of dissolution, and were the effect of the mineralizing waters themselves. The largest examble of the crustified vein is found in certain parts of the Montana Tonopah workings, where the cavities were sometimes two or three feet in diameter and gave rise to well banded ore.

The fractures transverse to the main system have also a not inconsiderable effect in determining the course of the ore-bearing solutions. Along important transverse fractures I have found that the vein narrows, the cross fractures playing the same part as the lateral wall fractures, even if not always to such an extent, and so earning the name which I have given them, of *cross walls*. I am not aware that this feature of cross walls in vein structure has ever before been recognized, but it is a conception that is extremely important to the miner. It can readily be seen that once the conception of the

main vein as due to the effect of maximum circulation along an especially fractured zone is understood, the effect of strong cross fractures in limiting or even locally cutting off the circulation from some portions of the vein zone becomes clear and even follows naturally and almost necessarily. To these cross walls, more or less pronounced, the division of the water circulation along the main zone into columns of unequal importance was due, and hence the mineralization accomplished by these waters was correspondingly localized. It is probable that the recognized ore shoots or bonanzas had their origin in this way.



Cross-wall in Montana Tonopah vein. a—rich ore, b—low-grade vein stuff.

The primary ores, where practically unaffected by oxidation, as in the Montana Tonopah and Tonopah Extension mines, consist mainly of solid sulphides. The gangue of these veins is chiefly fine-grained quartz, with a great deal of potash feldspar, adularia, a pure variety of orthoclase. Sericite, the fine variety of muscovite, is also frequently present, and sometimes also a mixed carbonate of lime, iron, magnesia and manganese. The principal metallic mineral of the ores is argentite, and there is considerable polybasite and probable stephenite, often in characteristic crystals. Chalcopyrite and pyrite also occur, with some galena and probably some blende, although the latter mineral has not been detected in the hand specimen. Gold is present in the average ore in the proportion of gold to silver equals 1 to 100 by weight. It therefore makes up about two-fifths of the ore values,—the silver three-fifths. In the sulphide ores it has never been detected by the eye, whether in the hand specimen or under the microscope, although it has been found in metallic particles under both these circumstances in the partially oxidized ore. An analysis of the sulphide ores by Dr. W. F. Hillebrand shows about 2½% of selenium, part of which at least exists as a silver selenide.

There is no tellurium so far as yet determined. The veins

have been oxidized in part from the surface downward, but owing to the fact that there is no regular groundwater, the oxidation has been partial, extending very irregularly downward. Along veins the oxidation generally penetrates much deeper than in the rock, so that the ores may be partially oxidized while the country rock contains unaltered pyrite. This is plainly due to the greater rigidity and brittleness of the vein as compared with the rock, so that it has been more fractured by strains and affords a readier channel. Where veins do not outcrop but are covered with a blanket of overlying rock, there is usually comparatively little oxidation. In the ores the effects of oxidation are to alter pyrite into limonite, and also to deposit black oxide of manganese, which is formed from the manganese carbonate in the primary ores. Horn silver becomes abundant, and silver bromides and iodides sometimes accompany the chloride. The gold, which exists in some undetected combination in the sulphide ores, is largely deposited as metallic particles in the oxidized zone. Analyses of the typical ore of the oxidized zone, such as that in Mizpah vein, shows that it still contains a large amount of argentite. No important change in the amount of gold and silver, as compared with the unoxidized ores, has been proved. It is thus seen that the so-called oxidized ore of the Tonopah district, like that of many other deposits of desert regions, is really a modified ore, consisting of an intimate mixture of original sulphides and selenides, together with secondary sulphides, chlorides and oxides.

In both the oxidized and unoxidized zone secondary sulphides are frequent. These are chiefly pyrargyrite and argentite, and occur coating cavities which cut the primary ore. They are of later deposition than the primary ore, and are probably due to descending waters. They have not, however, so far as detected, caused any important readjustment in the values of the different zones.

In studying this mining district I have compared it with certain others which are closely similar to it. Probably the nearest analogies yet described anywhere in the world are the contiguous mining districts of Pachuca and Real del Monte, in Mexico. These are among the most important districts in Mexico, and have produced enormous quantities of ore. They

are situated in a range made up of Tertiary andesites, rhyolites and basalts. The veins are argentiferous with an appreciable amount of gold. They represent in a vertical sense two zones, the upper composed of oxides (red ores) and the lower of sulphides (black ores). The first, which has a downward extent of nearly 1,000 feet, contains chlorides and bromides of silver; the lower zone contains sulphides of lead, silver, etc. The lower limit of the upper zone corresponds to the groundwater level. The ore occurs in rich masses, called bonanzas, which are of irregular form. The impoverishment of the veins at great depth is admitted.

Besides these districts there are many others in Mexico which have been described as having very nearly the same characteristics. They occur chiefly in andesite. Senor Aguilera, Director of the Mexican Geological Survey, remarks in an article on the ore deposits of his country:—"It would be tiresome to enumerate all the silver veins of Mexico which occur in andesite, but it has been said that the majority of the silver veins are in various species of this rock, which Humboldt designated as metalliferous porphyries."

The Comstock lode, which lies nearly 150 miles northwest of Tonopah, presents also a very close analogy to it. The lode is formed along a fault line in Tertiary eruptive rocks, chiefly andesites. The lode material is quartz, certain limited portions of which contain large quantities of silver and gold, and so constitute bonanzas, while the rest is low grade. Most of the bullion has been derived from a black quartz like that of Tonopah, the color being mainly due to disseminated argentite, which is the principal ore mineral and which is accompanied by gold, probably free. Bunches of stephenite, polybasite and ruby silver were also found. In the bonanzas near the surface chlorides and native silver occurred. Frequently the ore grew base and carried quantities of galena, zinc-blende, etc.

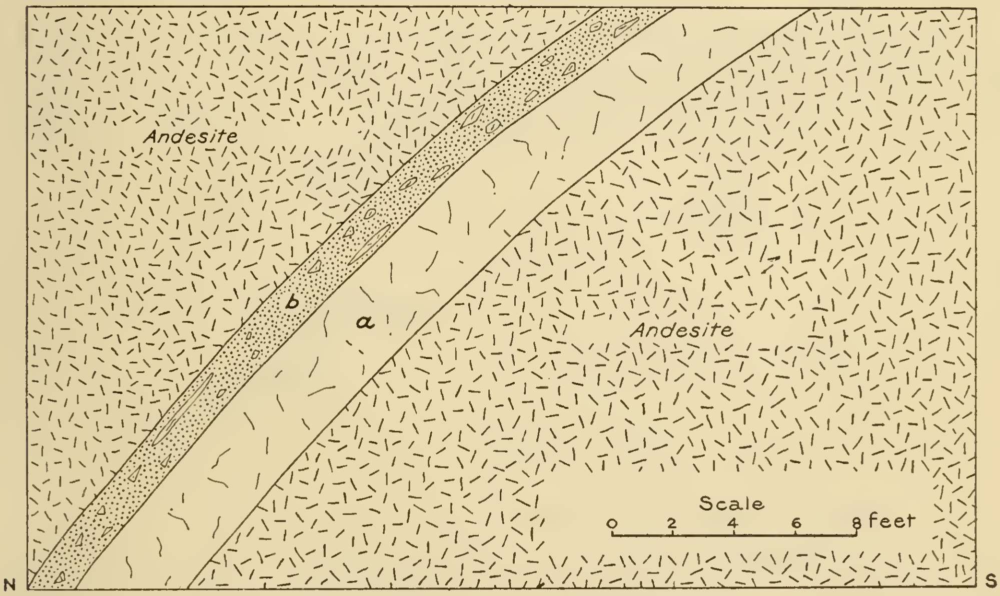
From these and other instances it appears that ore bodies of the Tonopah type occur repeatedly in the Tertiary volcanic rocks, especially in the andesites. In this connection it is interesting to consider the relation of the lavas in which the ores occur. The lavas of the Great Basin region of Nevada were studied by myself in 1900, and this study led to the conclusion that the whole region southward into the Mojava

desert, together with a portion, at least, of the Sierra Nevada, constitutes a petrographic province; that is to say, it is underlain by a single body of molten magma, which has supplied at different periods lavas of similar composition to the different parts of the overlying surface. The limits of this sub-crustal basin are not yet defined. Subsequently the studies of the Mexican geologist Ordonez extended this petrographic province into Mexico; and it is also probable that it extends a long distance northwest of Nevada.

In a paper published by myself in the Transactions of the American Institute of Mining Engineers I have subsequently brought forward the idea of a metallographic province, characterized by the presence of certain metals, and pointed out that these provinces may or may not be closely identified with petrographic provinces, though they probably are to a certain extent. Unquestionably the close relation between the Nevada mineral districts of Tonopah and the Comstock, with the far more numerous array in Mexico, and the individuality of this group as compared with other known veins of the world show a metallographic province which in this case coincides with a portion of the petrographic province previously mentioned. It is probable that the coextension of the metallographic and the petrographic province is greater than thus established. For at many other points along the belt of the petrographic province, in the Andes of South America, and elsewhere, veins are reported having, so far as can be made out, a similar mode of occurrence, age, and composition as those of Mexico. In general the Miocene andesites of this region are, as Humboldt noted, the metalliferous formation *par excellence*. And if the conclusions arrived at in the case of Tonopah are correct, the ore is due to the after actions of the eruptions, in the shape of fumaroles, solfataras and hot springs.

Besides the earlier andesites, some of the other volcanic eruptions of the Tonopah district were followed by ascending hot waters, which produced veins carrying some values in gold and silver. None of these, however, are comparable in size and importance to the veins of the earlier andesite. The chief of these lesser periods followed upon the eruption of the rock called the Tonopah rhyolite-dacite. On account of their resemblance of the earlier andesitic veins, these later rhyolitic

veins have been the object of recent exploration and development work, which on the average has been decidedly unprofitable. These veins are characterized by irregularity and a lack of definition and persistence, though their size may locally be great. The nature of the quartz is as a rule dense and jaspery, the color being white, gray or black. It is, therefore, usually of a different appearance from the white quartz of the early andesitic veins. The rhyolitic veins are usually barren, or contain only very small quantities of gold and silver, except locally, where rich bunches of ore occur. They are usually of irregular form and extent. A characteristic of the

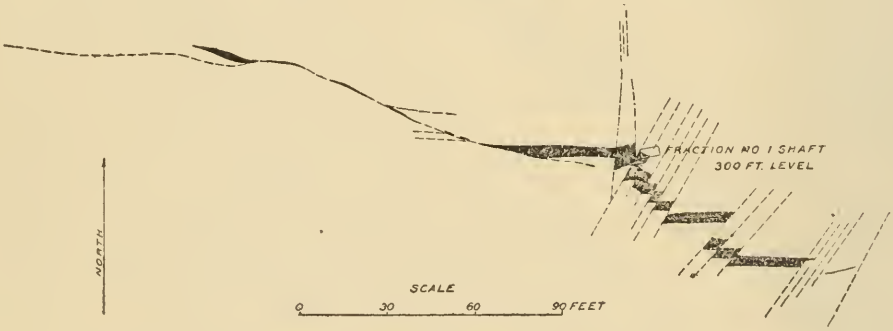


Cross-section of Tonopah extention vein, sh owing older, earlier andesite vein (a), and later filling (b) of rhyolite-docite period.

rhyolitic veins, to which there are, however, exceptions, is the greater ratio of gold to silver in them as compared to that in the earlier andesitic veins. The veins are, as a rule, confined to the rhyolite-dacite with which they are genetically connected. Yet in some places the waters must have traversed the andesite and found their way along the andesitic veins. Indeed it is along these brittle veins and the silicified adjacent andesite that fractures and fissures must have been most easily formed at this period, in the case of the Tonopah Extension an earlier andesitic vein has been reopened and along the hanging-wall a new vein of barren jaspery quartz formed. This is probably due to waters of the rhyolite-dacite period of mineralization.

The period of intrusion of the white rhyolite, which forms two of the hills near the town of Tonopah, was also accompanied by manifestations of hot spring activity. The top of Mount Ararat is composed of a volcanic plug of rhyolite. In this plug are veins which are locally as much as twenty feet thick, but are irregular and non-persistent. These veins conspicuously follow the contact and are co-terminous with it, and sometimes they cut across the rhyolite plug. They are fine examples of veins which have filled open fissures. The gangue consists mostly of brown and white calcite containing some iron and manganese carbonates, and low values in gold are frequently found.

In closing my address I will return to a subject of which I have spoken in general terms earlier, namely, the faulting of the veins as displayed in the mine workings.The complexity of

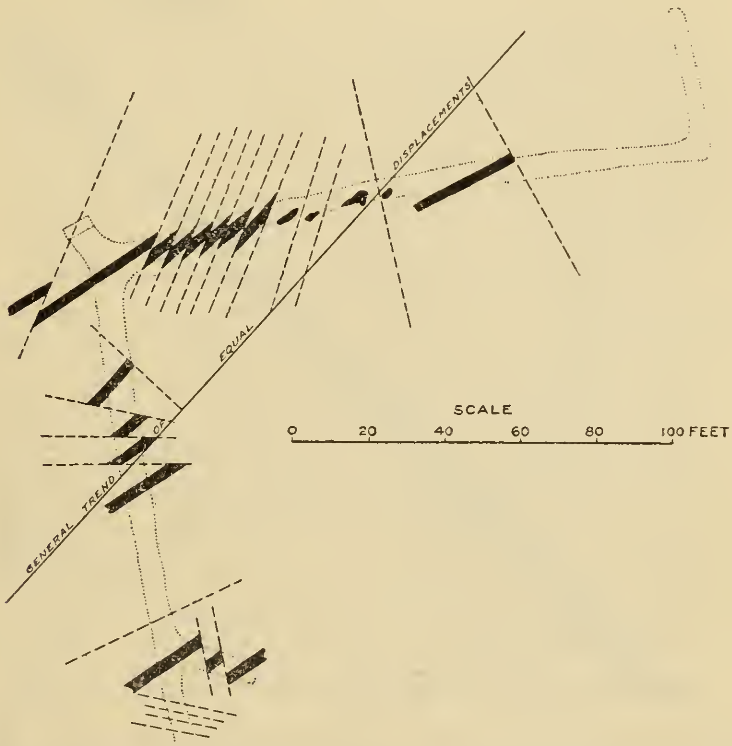


Faulting in Fraction mine. Horizontal plan. Dashed lines are faults.

faulting exhibited at Tonopah is greater than that in any reported district. It would be useless to describe all the variations of rock movement brought out by underground workings. I will briefly call attention, however, to some of the most interesting cases.

The Fraction No. 1 shaft was the first which encountered ore beneath the overlaping cap rock. Some of this ore was rich, but with development the vein was found to be so badly faulted that development has been for a long time discontinued Apparently originally there was a single vein, but it has been cut by numerous faults, which, however, may be separated into definite systems. The most important system strikes northeast and dips southeast 45°. By these faults the vein, as seen on a horizontal plane, is moved to the north on the west side. There are many of these, which disturb the faulting between

them and constitute a fault zone, whose limits and total displacement are not known. Abundant and strong striations on these fault planes, together with evidence afforded by the minute faulting and stringers and by the dragging of faulted veins, indicate that the general result was that the blocks on the west side of the separate northeast faults were shoved northward past the blocks on the east side, nearly horizontally but with a slight downward plunge. There is also a well marked system of faults striking north of west, sometimes parallel to the veins, but generally cutting across them at slight angles.



Faulting of "Wandering Boy" vein. Horizontal plan. Heavy black bands are veins. Dashed black lines are faults. Dotted lines show mine workings.

In cross section it is seen that the veins follow a series of pronounced rolls steepening and flattening alternately. In the mine it is evident that these rolls are the result of pressure and deformation in the rock, and are in the nature of folds. In the two upper levels, as shown in the cross section, at the sharp bend or apex of these folds, tangential fractures or slight faults leave the vein and pass off into the surrounding andesite. Between the 300- and 400-foot levels a flat fault striking and dipping in the same sense as the vein has probably the same

origin as the flat tangential slips in the upper levels, but is here of greater magnitude, so that the vein has actually been faulted considerably along it.

In the Wandering Boy workings also the veins are thrown into great confusion by faulting. Analysis of this disturbance leads to the conclusion that the faulting can be referred to two major systems, that of the Wandering Boy fault, which strikes northwest, and that of the Fraction fault, which strikes northeast. On the 300-foot level of the Wandering Boy the faulting

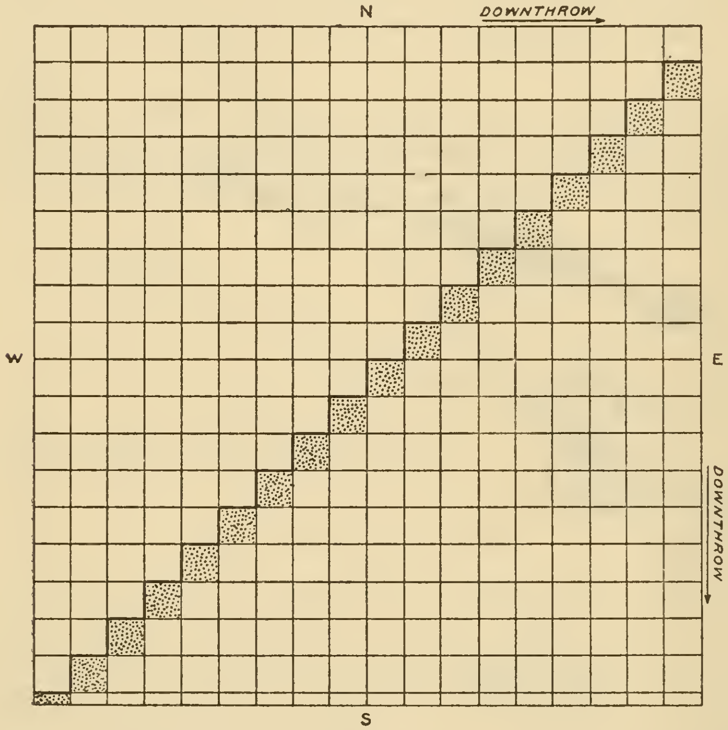
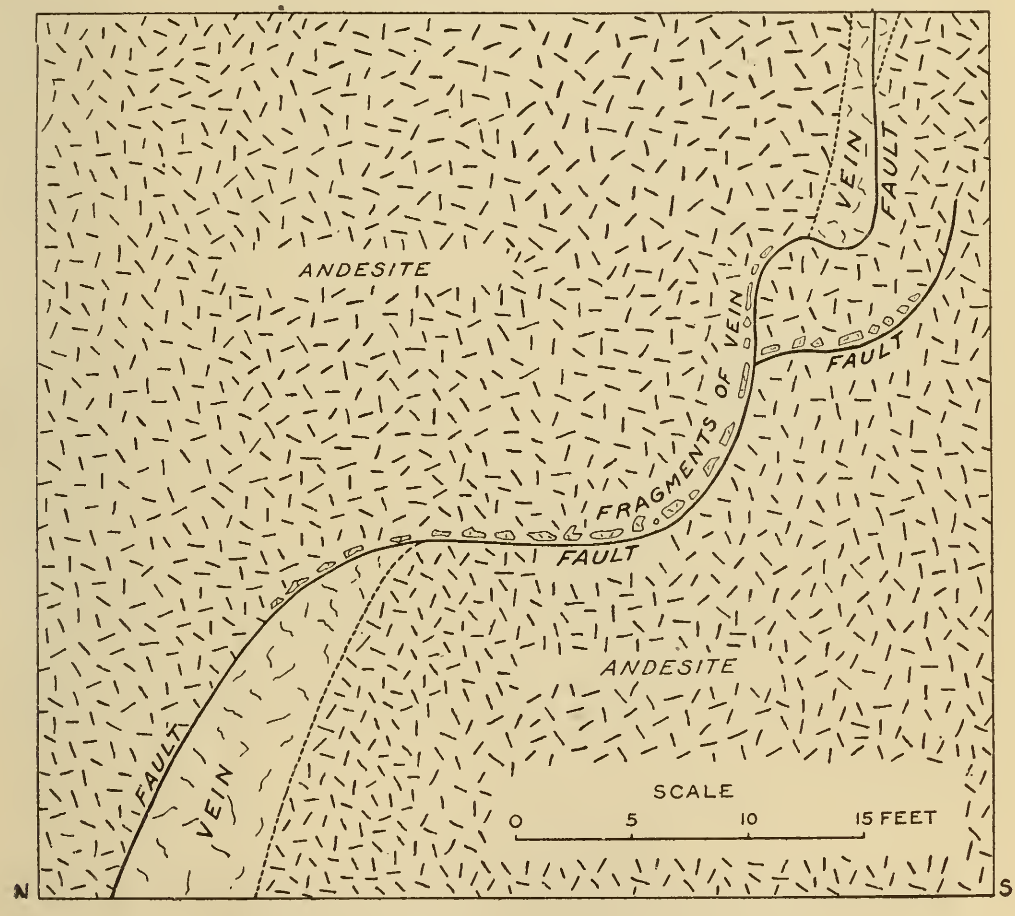


Diagram showing horizontal plan of equal and equally special faults belonging to two interesting systems at right angles to each other; the north-south system having a regular downthrow on the east, and the east-west system a regular downthrow on the south side. The heavy zigzag line represents one of the lines of equal faulting; the shaded squares, one of the zones of blocks of equal displacement.

is highly interesting and complicated. The main workings consist of two drifts at right angles, one running nearly east and the other south. The vein in this level is three to four feet thick, with a northeast strike and a dip of 30° to 40° southeast. The east drift therefore runs somewhat diagonally to the strike of the vein, though more nearly along the strike, while the south also runs diagonally, though also somewhat more across the strike. Near the end of the south drift a short east drift has been run. In all these drifts the vein, which

normally from its strike and dip would disappear, is continually thrust up by close set faults, so as to persist in the workings.

On the east drifts the faults have a north-south trend, while those of the south drift are essentially at right angles; therefore the vein may be considered for the sake of clearness as cut by two intersecting systems of faults, one striking north and south and the other east and west. By the former the vein is



Curved faulting of vein. The Montana Tonopah mine.

repeatedly upthrust on the east, and by the latter repeatedly upthrust on the south.

In order to understand the resultant effects of such intersecting faults, let us take a simplified example. Let us take a rectangular block which has been affected by two sets of vertical faults striking at right angles to each other. The result is that lines or planes of equal displacement are zigzag, made up

of regularly alternating portions of each of the two fault systems, while the trend of the whole zigzag, and therefore of the lines of equally displaced blocks, is diagonal to both the fault systems. From this simple case the variations and irregularities may be ideally deduced. In all cases it appears to hold good that the zones or blocks of equal displacement, roughly aligned though these may be, trend diagonally between the two fault systems. In the case under consideration the problem takes on an added complexity, because the vein dip enters as a factor. The dip in this case is opposite to the downthrow of the faults, and the angle of the dip and the displacement and spacing of the faults are such that one offsets the other and the vein continues in a horizontal zone. This explains why the drifts all encounter blocks of the same vein, and it follows that other blocks exist on this level so far as this peculiar intersecting faulting and the balance of the dip and displacement is maintained.

In the Montana Tonopah the Macdonald vein has been affected by complex faulting. In vertical section such faults appear nearly parallel to the vein, though curved and branching, and so become now steeper, now flatter in dip than the veins. The line of faulting is not parallel in strike or dip to the vein, however, though it so appears in vertical section. In fact, the flat portions of the fault zone pitch east on the vein at moderate angles, and striae along the faults show that the real direction of movement has been to the east along this pitch. In horizontal section these faults are seen to curve and branch in as complicated a manner as in the vertical section, producing an added complexity.

EUTECTIC COPPER.

The autectic is that mutual mixture which freezes out last, after the ingredient which is, or the ingredients which are, in excess shall have been removed by gradual cooling. In the case of casting copper, some cuprous oxide is sure to be formed; here the eutectic is a mixture of copper metal and 3.4 per cent. of cuprous oxide, or 0.38 per cent. of oxygen. This eutectic can be seen under the microscope as a thin groundmass surrounding grains of pure copper. It is transparent; blue, in reflected, and red in transmitted light. This eutectic may be a source of weakness, as in copper tubes which carry hot and reducing gases, when the resulting action may form fine cracks by forcing the metal apart, a condition popularly known as the "hydrogen disease" of Hehn. This general problem of the eutectic of copper, tin and oxygen has been the subject of a recent paper by O. Bauer in a recent number of the *Zeitschrift für angewandte Chemie.*

GEOLOGIC MAP OF TONOPAH MINING DISTRICT

ELECTRICAL SECTION.

(Stated Meeting, held Thursday, March 16, 1905.)

The Development of the Manufacture of the Edison Incandescent Electric Lamp—1881-1905.

By J. T. Marshall,

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[In this paper the author gives a detailed account of the successive steps in the development of the Edison electric incandescent lamp from the period of its appearance as a commercial product in 1881 to the present.—The Editor.]

The writer has been continuously in the employ of the Edison General Electric Company, and its predecessors, since October, 1881. In that year there were made in the United States about 34,000 very crude looking Edison incandescent electric lamps,the greater number of which were 16 C.P., 100 to 110 volts, and 5.8 W.p.C., or eight lamps per horse-power. Their average life to the breaking point was about 3000 hours, but they declined so rapidly in Candle-power as to be very inefficient long before they broke. Lamps then sold for 65c. apiece, but the cost was more than double this, so that they were manufactured at a loss.

In 1904, there were made in the United States over 45,000,000 Edison incandescent electric lamps, of artistic appearance, the greater number of which were 16 C.P., 100 to 120 volts, and 3.1 W.p.C., or fifteen lamps to the horse-power. The average life to the breaking point of lamps as now manufactured is 800 hours, and until the end of their lives the candle power is very much better maintained than it was in the 1881 lamp at 5.8 W.p.C. If the present lamps were to be burned at 5.8 W.p.C., or at the efficiency at which the old lamps were burned, the life would be 25,000 hours, or over eight times as long as that of the old lamp. Lamps are now sold for an average of 16c. apiece. The number of lamps now made per operator in the

Company's factory is several times the number made per operator in 1881.

It is the object of this paper to trace out the development of the lamp to its present stage from the stage in which the writer found it, so as to show what has brought about the improvement in quality and appearance, and the decrease in cost.

It would be interesting to go still further back, and show step by step the development of the lamp in the laboratory before commercial manufacture was begun, but that would lead the writer outside the field of his personal experience, and for that reason it seemed better to restrict this paper to the scope indicated. For the same reason it was deemed advisable to change the subject from "Twenty-five Years of Electric Lighting" to "The Development of the Manufacture of the Edison Incandescent Electric Lamp, 1881-1905, inclusive."

For purposes of comparison, only the 16 C.P., 100 to 120 volt typical lamp of its time will be considered.

In 1881, the Edison lamp consisted of a conducting filament of carbon enclosed on a vacuous glass globe, and connected through leading-in wires to a source of electric current, which caused the filament to glow. The component parts of the lamp were the filament of carbon, the leading-in wires to which the filament was attached, the glass stem into which the wires were sealed, the joint or clamp by which the filament was secured to the wires, the bulb into which the stem with the filament on it was sealed, and the base to which the exterior ends of the leading-in wires were attached and which, when screwed into the socket, connected the filament to the source of current.

The Edison lamp of to-day has the same component parts; not one has been added, unless the anchor be considered an addition, nor has any one been taken away; all have been more or less modified and improved.

In Fig. 1 are shown the lamp of 1881 and the lamp of 1905.

A is the filament. In the old lamp it is hair-pin shaped and made from carbonized bamboo. In the new lamp it is coil-shaped, thinner, and about twice as long as in the old lamp, and is made from carbonized artificial cellulose.

B shows the leading-in wires of platinum. In the old lamp they are longer than in the new lamp.

C is the stem made in both lamps from a piece of glass tubing.

D is the joint or clamp. In the old lamp it is made of a piece of flattened copper wire folded over the shank of the filament and copper-plated to it. In the new lamp it is made of carbon paste which cements the filament direct to the platinum wire.

E is the bulb. In the old lamp it was "free blown," so that no

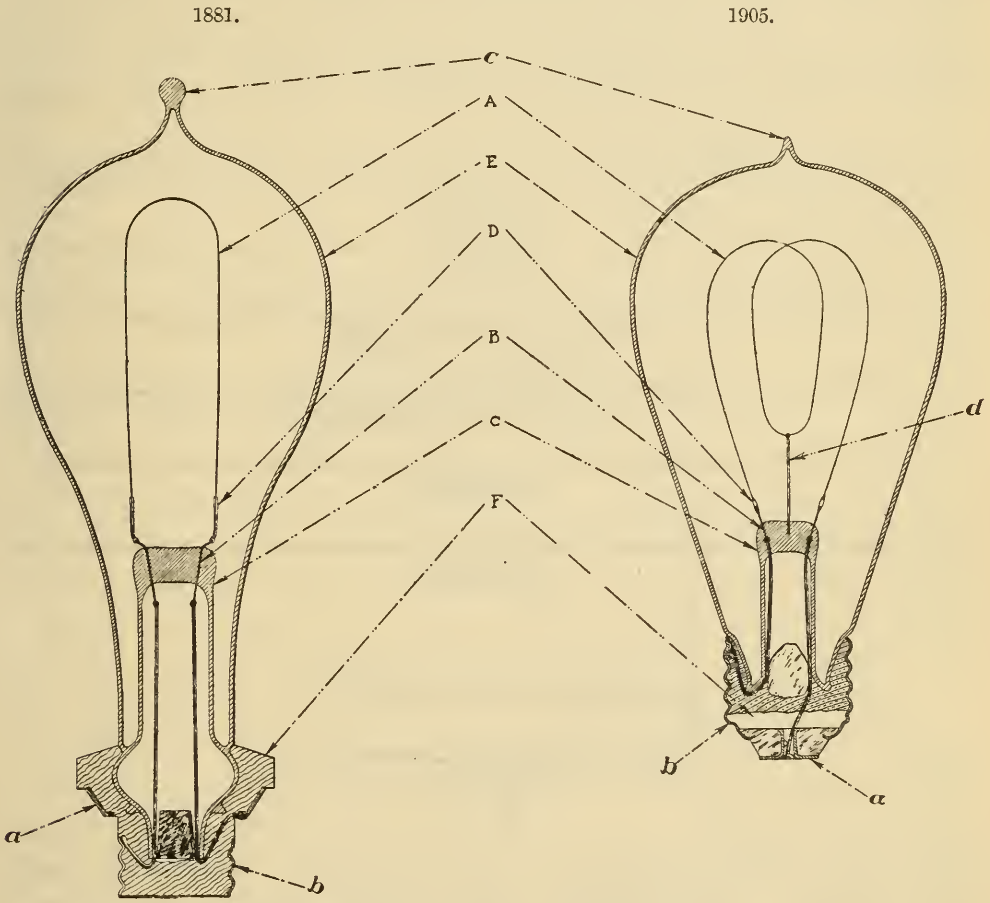

Fig. 1.—The Edison Lamp in 1881 and 1905.

two bulbs were the same size and shape. In the new lamp it is moulded, so that all bulbs are just alike.

F is the base. In the old lamp it consists of a brass ring (a) and a screw (b) assembled and secured to the lamp with plaster of Paris. In the new lamp it consists of a cap (a) and a shell (b) assembled with molten glass and secured to the lamp with a special cement.

c is the tip left from closing the lamp after exhaustion.

d is an iron wire support or anchor to stiffen the filament, and is the only part in the new lamp that does not appear in the old one.

The bamboo splint from which the filaments were cut was 11″ long, $\frac{3}{8}$″ wide and about $\frac{1}{16}$ of an inch thick with the bark or skin on. It was submitted in turn to the operations of splitting into strips, planing off first one side and then the other, shaving off the bark, and cutting out between the shanks on the end. The work was done by hand on specially designed splitters, planes and molds, and compared with recent methods involved an enormous amount of labor. The shank left on the

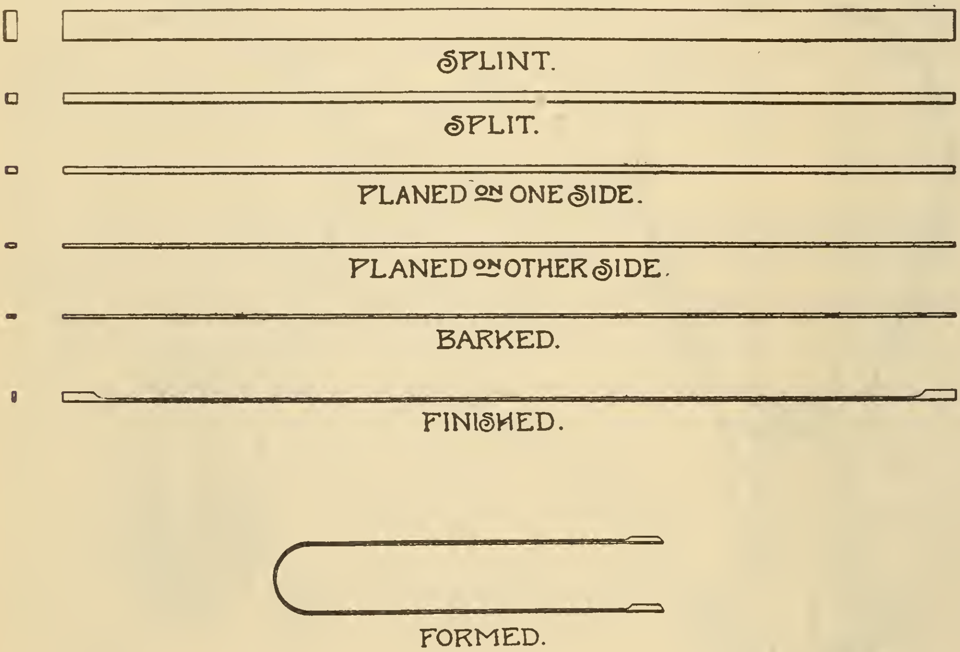

Fig. 2.

end of the filament gave it a broad contact with the clamp, and prevented the heating and volatilization of the copper-plated clamp which would otherwise have occurred.

Fig. 2 shows the filament after each operation.

The shank was very objectionable. It complicated the operation of cutting the fibre, and fixed the length of the fibre so that it could not be subsequently changed to produce different candle-powers and voltage. The filaments were carbonized by heating them in forms stacked in a closed cubical plumbago crucible. At first only one filament was put in a form and the shank prevented more than a few being put in under any cir-

cumstances. The substitution of the carbon paste, which did not volatilize with heat, for the copper-plated clamp which did, permitted the abandonment of the shank, so that filaments could be cut somewhat longer than they were to be used in lamps, more of them could be packed in forms, and they could be cut after carbonization to the length which would give the right volts. It was customary at one time to take sample carbons from each crucible, make them into lamps, determine their voltage at 16 candles, and then cut the remainder of the filaments short enough to give their right volts. This was necessary because of the uncertainty of getting two carbonizations alike. Varying efficiencies resulted from this practice, but at that time the importance of efficiency was not appreciated as it is now. As long ago as the fall of 1881 it was realized that 5.8 Watts per candle was undesirably and unnecessarily low efficiency for lamps that would burn 3000 hours, and the standard was changed to $4\frac{2}{3}$ Watts per candle power, or ten (10) lamps per horse power, by cutting the filaments shorter and smaller. This reduced the life.

The increase of electric lighting created a demand for lamps that would absorb less energy, and at the same time not be reduced in life. Mr. Edison set himself to working out this problem, and in 1887 got out a lamp of 3.1 Watts per candle, or fifteen (15) lamps per horse power, made from a bamboo filament coated with a preparation of asphalt, which gave it a dense shiny surface. This made a very much better lamp.

In 1892, we began to use treated bamboo filaments. Treating consisted in bringing the filament to a high incandescence by means of a current while the filament was surrounded with a hydro-carbon vapor. The heat decomposed the vapor and deposited a coating of carbon on the filament. There were several distinct advantages in treating. Not only the right voltage, but also the right efficiency could be obtained from a given size filament by cutting it the right length and treating it to the right resistance, and we began to make the filaments longer and smaller. The treated bamboo filament had a longer life than the untreated bamboo filaments. The increased life was due to the fact that the character of the treated surface was such that at a given efficiency the temperature of the filament was lower.

It was not long after this that we began to use what is called the squirt filament. This is produced by dissolving cotton in zinc chloride or acetic acid, and squirting it through a small hole into alcohol or water to harden it. In this way many hundred yards of round, smooth filament of nearly uniform cross-section may be squirted from the contents of a quart bottle of solution. This filament has to be washed, dried, shaped, packed in crucibles, and carbonized. The squirt method of producing filaments is so much more efficient than making them from bamboo that only between three and four per cent. as much labor is required, and very much less material. The squirt filament besides being longer lived than the bamboo filament has the advantage that it is possible to get it any desired length, whereas the longest possible length to get bamboo between the joints is fifteen inches (15″), which will make a filament less than twelve inches (12″) long.

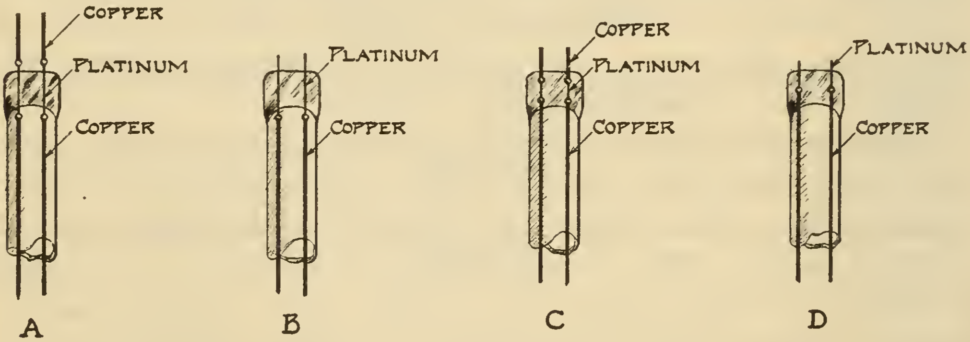

Fig. 3.

To get the full benefit of the treatment on a filament it is necessary that it should not be less in thickness than a well defined minimum, and this thickness can only be obtained by using filaments much smaller in cross section and much longer in length than either the treated or untreated bamboo filaments. This increased length is what makes it desirable in the latest type lamp to have an anchor to steady the filament. The treating process, of course, involves additional operations and consequent additional expense, but the improvement in the quality more than compensates for the additional cost.

The leading-in wires are of platinum welded to copper. Platinum is used because it can be sealed into glass and make an air-tight joint. Many substitutes have been tried with some degree of success, but we have never felt that it would be

safe to adopt any of them. The wires in the old lamp were $\frac{1}{2}''$ long, and .012″ diameter, as shown in Fig. 3,—A for copper clamps and B for paste clamps. They were made as long as they were to avoid having the weld between the copper and platinum put in the glass seal, and they were made as large as they were to prevent mechanical breakage of the platinum just where it entered the glass. Later the size was reduced to .010″. Long before the welds were put in the glass, it was repeatedly suggested that it should be done to permit the use of shorter platinum, and to transfer the strains to the copper, which was stronger. The suggestion was always met by the

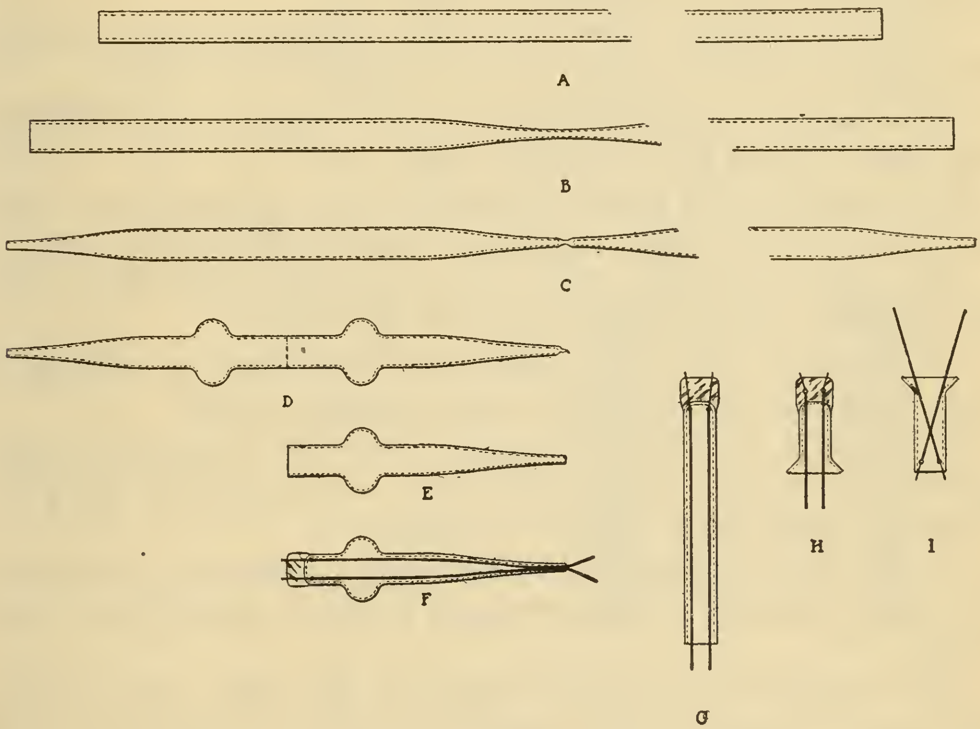

Fig. 4.

statement by the head glass blower: "That was tried at Menlo Park, and it caused all the glass seals to crack." In the meantime the price of platinum was rising, and Mr. Edison set about to reduce the amount of platinum. He did this, as shown in Fig. 3 C, by using a piece of platinum $\frac{1}{8}$ of an inch long and .005 inches diameter, thereby reducing the amount of platinum to $\frac{1}{16}$ of what had been used before. This piece of platinum was completely embedded in the glass, and copper wires protruded both into and out of the lamps, leaving four (4)

welds in the seal; just why these failed to crack the seals was never explained. The .005 wire was large enough to carry the current, and being relieved of all mechanical strain met all requirements, the copper wire was not found advantageous to clamp the filament to, and was abandoned as a clamp wire, after many inferior lamps had been made; the platinum wire was then run into the lamp, but the weld was kept in the seal, as shown in Fig. 3 D. The amount of platinum now used in a lamp is about one-eight as much as was used in 1881.

Fig. 4 shows an inside-part or stem in the various stages of manufacture, as it was made in 1881.

A, is the tubing as received from the glass factory, except that it has been cut to the proper length for four stems.

B, shows it with points drawn on it by heating the middle of the tube in a gas fire and stretching it out.

C, shows it as it appears when B is cut in two in the thin part, and the open ends are melted together and drawn out.

D, shows two globes blown on it by heating the tubes in the proper place, and blowing it up with the breath.

E, shows it cut in two pieces for two stems by scoring it with a file between the globes, and breaking it apart.

F, shows it with the wires sealed into it by heating the open ends in the fires, inserting the wires, and squeezing the glass down on them with suitable tweezers.

Each stage was produced by a different operator, except that the same operator produced stages B and C, and all was hand work.

The purpose of the globe blown on the stem was to make the stem fit into the bulb when the bulb was blown off, and just here it will be well to consider the bulb sufficiently to show its relation to the stem.

Fig. 5 shows the free blown bulb of 1881.

A, just as it was received from the glass works.

B, with the tube attached to the top, through which the lamp is to be subsequently exhausted, and with the neck blown off ready to seal the stem into it.

C, with the stem inserted ready to be melted to the neck of the bulb.

D, with the stem melted in.

To do this the operator held the top tube of the bulb in one hand and the stem in the other, and rotated them in the fires, holding the combination horizontal during the process. In melting the stem and bulb together there was a tendency for the glass to contract and thicken, so that it was blown into from the top and also from the bottom from time to time to keep it in shape. The globe on the stem was blown somewhat thinner than the rest of the stem, and this was thought to prevent a tendency to crack where the stem and bulb were joined together. That part of the stem which projected below the

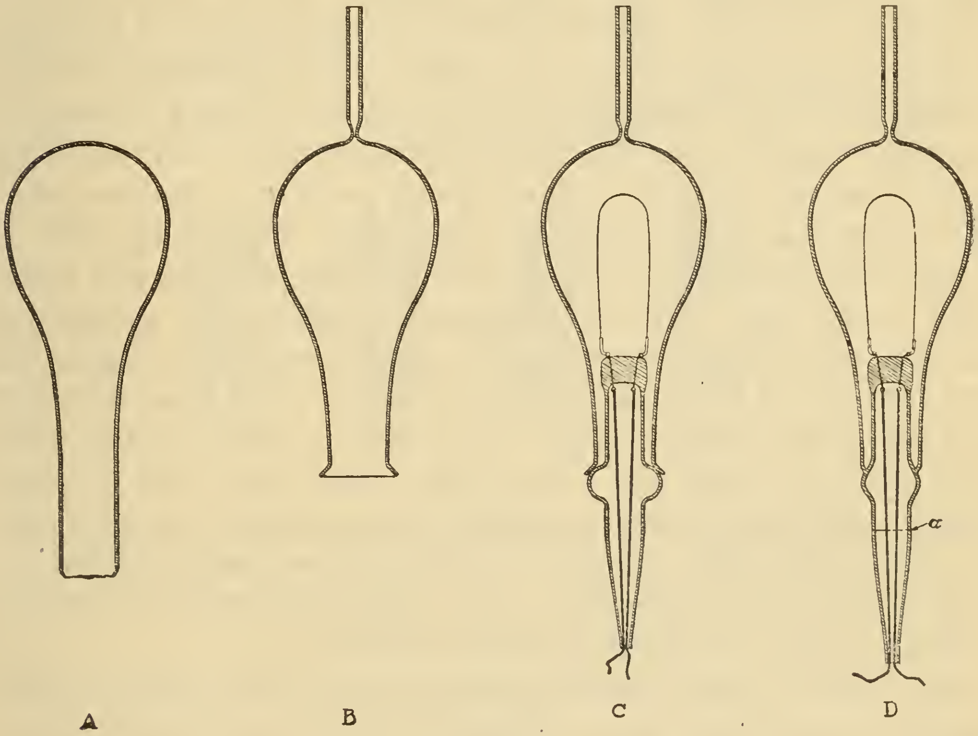

Fig. 5.

lamp was cut off, and thrown away. The only purpose of this waste glass was to form a handle for the operator during the process of sealing it.

The first departure from this type of stem is shown in Fig. 4 G. Here the globe was omitted, and at the same time a machine was designed which held the bulb and stem in position, and rotated them in the fire while being sealed together. There was still a piece of waste glass to be cut off and thrown away, and there was a further disadvantage in this type of stem, that in melting the glass of the bulb down on the glass

of the stem there were unequal strains produced, which caused a good many cracked seals. If the stem was of softer glass than the bulb, the crack took place across the joint; if the stem was of harder glass than the bulb, the crack took place along the joint. It is not easy to obtain glass always alike, so it is necessary to adapt methods suited to these variations.

Fig. 4 H shows the stem now used. This is made from a piece of tubing cut the proper length and flared at one end. It could be sealed into the bulb on the same machine used with the previous stem, but it was necessary to have a holder to slip into the stem to take the place on the machine of that part of the stem previously thrown away. This stem had the advantage of not producing any waste glass. It has a further advantage that the per cent. of cracked seals is very much reduced, because instead of the lap-seal we have a butt-end seal. This stem was at first made by revolving a rather long piece of glass tube by hand over a pair of rollers, keeping the end of the tube in the fires. When the glass was sufficiently softened, a carbon pencil was inserted in the softened end at an angle, and the rotation of the tube produced a flare. The stem was then cut off to the proper length. This proces was repeated until the tube was used up. Later the glass tube was cut into proper lengths for stems, and the pieces inserted one at a time in a little lathe-like machine, which gripped and revolved the end of the tube in the fires. The flare was produced by the carbon pencil as before, and then ejected.

For quite a time after the latest type of stem was adopted, the wires continued to be sealed into the stem by hand with a small specially-designed tool for holding the glass. Later a machine was designed to hold the glass and wires,rotating them in the fires, and squeezing the melted glass down on the wires. The relative positions of the glass and wires on this machine are shown in Fig. 4 I. The machine had four rotating holders, each of which could be successively revolved in four different positions; following one of the holders around in all four positions; in the first position the stem and the wires were placed on the holder; in the second position a soft flame played on the lower end of the tube to heat it slowly to prevent cracking; in the third position a sharp flame played on the lower end of the tube to thoroughly soften it, and a pair of pincers squeezed

the glass on the wires. In the fourth position the finished stem was unloaded from the holder. This machine increased the output of an operator, and had the further advantage of bringing the ends of the platinum wires up against a stop, so that both wires protruded an equal amount beyond the end of the glass. This was one of the factors which entered into the problem of shortening up the platinum wire.

The joint made in 1881 is shown in Fig. 6, A to C inclusive.

A, with short pieces of copper wire welded to the platinum wires.

B, with the wires bent over hook-shape, and flattened on an anvil with a blow of a hammer.

C, with the flattened hook bent over on itself enclosing the filament, and with the joint copper-plated.

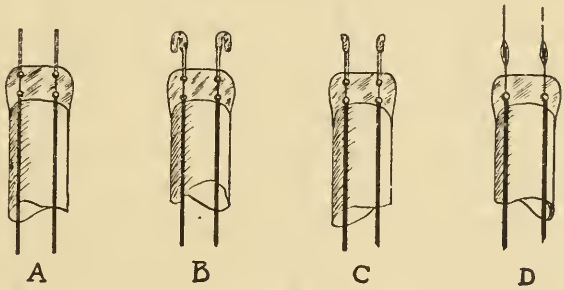

Fig. 6.

The plating was necessary, because the folding of the flattened wire over the shank of the filament made a bad mechanical joint. The plating was done in a wooden trough, having holes in the bottom in which were placed perforated rubber corks, through which the tube of the stem fitted so as to make a water-tight joint. The wires at the bottom of the stem below the trough were all connected together electrically to one pole of a battery, and there was a grid of copper in the bottom of the trough connected to the other pole of the battery. The trough was filled with a sulphate of copper solution, and the stems were slipped in the perforated corks until the liquid came the proper height on the clamps, and the plating was continued until the proper thickness was attained. Plating was a very cumbersome, and expensive operation, and was soon superseded by the paste joint, as shown in Fig. 6 D. The paste as first used was a mixture of very fine graphite, Chinese ink, and water. This answered the purpose pretty well, but the

joints were not as strong as desirable, and there were certain ingredients in the binding material of the ink which caused a discoloration of the bulb, so that this clamp was afterard superseded by one containing certain proportions of graphite and gum, and this is the kind of clamp used at the present time. Since the time the paste clamp was adopted, the clamping has been done by daubing a small quantity of paste on both the platinum wire and the end of the filament, and sticking the two together. This was the method when paste as first adopted, and it is still the method; that is, it is one of the operations in

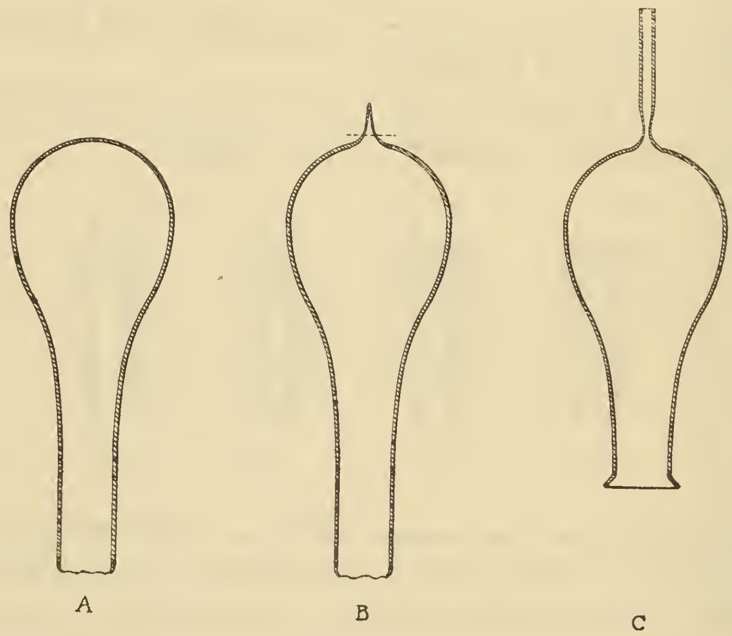

Fig. 7.

which we have practically made no improvement in the last fifteen years.

The bulbs, as heretofore stated, were first made free blown, so that no two bulbs were the same size and shape.

Fig. 7 shows the bulb in the different stages of manufacture.

A, just as received from the glass works.

B, with a tip drawn or punched on the top, to be cut off as indicated on the dotted line so as to leave a small hole.

C, with the short glass tube attached to the top, and with the neck blown off for the reception of the stem.

In the early stages of lamp manufacture the bulbs were sent to the operators who sealed the stems into them in just the condition that they were received from the glass works, except

that they were washed. The operator heated a small spot in the top of the bulb, stuck a stick of glass into the heated part, and pulled out a slight point, which he cut off with a file. This left a hole in the top of the bulb. To this hole he joined a short piece of tubing through which the air was subsequently to be exhausted from the bulb. Then he picked up one of his stems, and by comparing it with the bulb he saw the length that the bulb should be cut. He cut off this bulb by rotating it in the fires at the proper place, pulling off the neck and blowing out the melted end. Then he sealed the stem and bulb together as previously described, attached little glass prongs just below the joint of the stem and bulb to serve as anchors to hold in the plaster of the base, and cut off the stem below the joint. It was soon found advantageous to divide the operations of tubulating the bulb and sealing the stem into the bulb among two operators, one of whom did the tubulating, and the other the sealing-in. It was further found advisable to punch the little tip in the top of the bulb before sending it to the tubulator. This was done on a machine which held the bulb in a vertical position, neck up, over a gas flame which heated a spot in the top of the bulb. A pointed punch was then brought down through the neck of the bulb, which pressed the tip out. After these operations had been separated for some time, they were again brought together by supplying each operator with a bulb punching machine, on which one bulb was being heated while another was being tubulated, and in which the punch was operated by the foot. For many years the small top tube was joined to the bulb by hand, but for several years the tubulating has been done on a little machine on which the bulb is held vertical, mouth downward, and the short piece of top tube is held just over the hole in the top of the bulb, so that four small flames were directed on the point of juncture at the same time that the bulb and tube are slowly rotated. When the two are melted together, the joint is stretched a little so as to produce a contraction, as shown in the figure. At the same time that this machine was designed, a machine was designed for making the hole in the top of the bulb. This was done by heating the top of the bulb with a very small sharp-pointed gas flame at the same time that air pressure was introduced into the interior of the bulb. When the glass became soft enough, the

air forced its way through and made a hole, whose size could be regulated by the air pressure. With high pressure the glass yielded when only a very small area of glass was heated, and the hole was consequently small; low pressure did not blow through so soon, and made a larger hole. The machine for making the hole in the top of the bulb, and for tubulating the bulb was worked by one operator. The use of the tubulating machine resulted in more and better work.

The method of blowing off the bulb suited to each particular stem resulted in the production of lamps which varied considerably in length from the bottom of the base to the top of the bulb. It also resulted in a great difference in diameter where the base was attached to the bulb, so that there was always a compromise between making bulbs to fit the base, and making bases to fit the bulbs. With the advent of the tube stem, it was found that the bulb could be made to fit the base better by blowing it off about one-half inch below the point where the diameter of the neck was the same as the diameter of the shell, and bulbs were gauged out into different lots according to the length from the top of the bulb to the point where it was the diameter of the shell, and different length bulbs were used for different candle-power lamps. Soon after the bulbs began to be gauged in this way, a machine was designed for blowing off the necks of the bulbs before they were sent to the sealers-in. This machine rotated the bulb rapidly in a horizontal position, and had guides which brought the bulb in the proper place to be blown off correctly. Later a blowing-off machine was devised, which held the bulb in a vertical position, neck downward, and at the same time rotated it in the fire. When the glass was sufficiently heated, the weight of the neck caused it to drop off, and at the same time air pressure was introduced through the top of the bulb, and blew off the film of glass which naturally formed over the mouth. This latest blowing-off machine is placed opposite the sealing-in machine, so that the same girl operates both.

The force of habit is very well illustrated in the development of glass-blowing machinery at the factory. A hand operator naturally holds his work in a horizontal position, and this habit seems to be the only explanation for the fact that the first flaring machines, the first sealing-in machines, and the first blow-

ing-off machines all held the work in a horizontal position. This was very awkward, because a holder had to be provided which held the parts positively, and the tendency of gravity was to get the work out of symmetry. When machines were devised which held the work in a vertical position, it was only necesary to drop the parts on holders, where they tended always to assume a symmetrical form. It now seems strange that anyone should have attempted to perform these operations in any other position.

In speaking of the stem tube mention was made of the fact that a machine was designed which held the bulb and stem in position, and rotated them in the fire while being sealed together. As this machine held the work in a horizontal position, it was not easy to get a holder for the latest type of stem, which would fit all of the stems. Glass tubing is made now in the same way as it was many hundred years ago, and it is not possible to make it uniform in diameter. Hence, the necessity of making a holder which would fit all diameters of tubes. The difficulty of doing this is probably what first suggested holding the stem in a vertical position, and a machine was devised very similar to the machine used for making stems; in fact, it was used before the stem-making machine was developed. The four holders are adapted so that the stem is set on a stud which runs up inside of it, and the bulb is slipped over the stem with the filament on it, and rests on a holder so that the neck of the bulb and the flare of the stem are in the proper relative positions. This is done in the first position of the holder. In the second position, a soft flame is directed at the place where the joint is to be made. In the third position, the two are melted together in a hot flame, and in the fourth position the lamp is removed from the holder.

The desirability of having bulbs uniform in size was apparent very early in the history of lamp manufacture, and from time to time bulbs blown in moulds were tried. With the earlier type of stems it was found that the number of cracked seals was very much increased, and so free-blown bulbs were used for a long time after we wished to abandon them. When the latest type of stem was adopted, it was found that they could be sealed into moulded bulbs with very little breakage, due to the

different character of the joint, and the moulded bulb was adopted, and has been in use for about fifteen years.

In Fig. 8 are shown the different stages of development in the base.

A, with the ring and shell assembled with plaster.

B, with the cap and shell assembled with plaster.

C, with the rim of plaster left off at the top.

D, with the shell and cap assembled with porcelain, and attached to the lamp with plaster.

E, assembled with glass, and attached to the lamp with plaster.

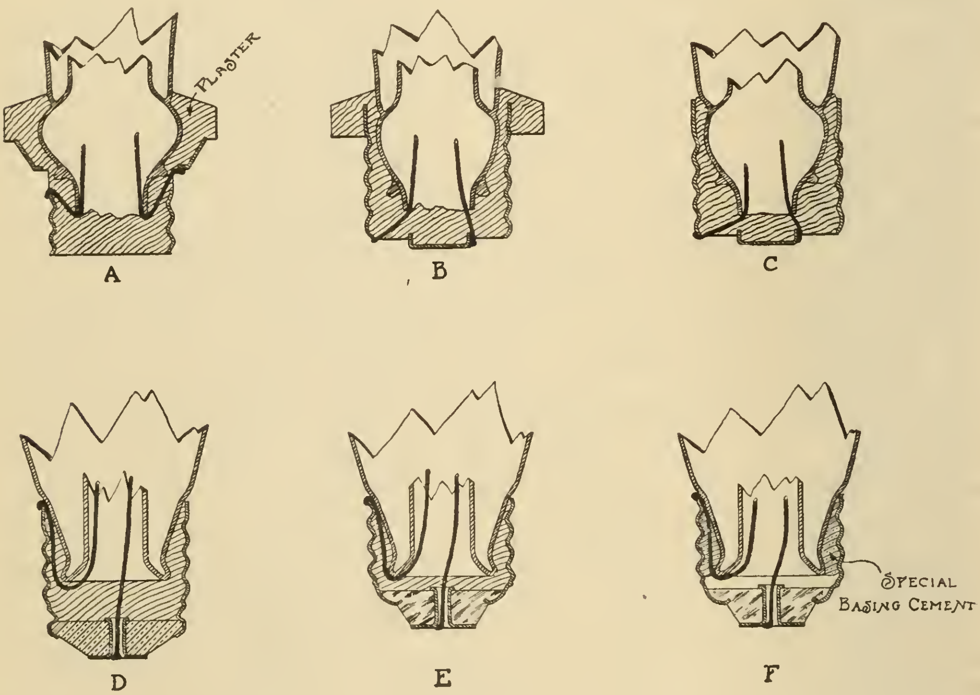

Fig. 8.

F, assembled with glass, and attached to the lamp with a special basing compound.

In A, B and C the brass parts were placed in a mould, which was then filled up with plaster of Paris, mixed thin enough to be poured. The lamp was set into it and allowed to stand until the plaster hardened. The thick rim of plaster at the top of A was necessary in order to make the plaster strong enough to hold the rim. It was soon found that screwing the lamp into the socket put a tensile strain on the plaster, and easily broke it apart. For this reason the base made with the cap on the bot-

tom instead of a ring at the top was substituted. Screwing this base into the socket caused compression instead of tension, which the plaster was better able to sustain. At first this base had the thick rim of plaster at the top, not because it was necessary for strength, but because the shells did not fit the neck of the lamp, and it was thought to present a better appearance. Later the rim was abandoned, and this left some exposed plaster between the shell and the neck of the lamp. Very often the lamp was not set centrally in the shell, and this presented a bad appearance. To overcome this the shells were turned in at the top to different diameters, and the lamps were sorted out to fit the different diameter shells. Later when the tube type of stem was adopted, it was found that the bulb could be blown about one-half inch below the point at which this diameter was the same as that of the top of the shell, and shells were afterwards made turned in all to the same diameter. This enabled us to use one type of shell, but it resulted in a still greater variation in the length of the lamp from the cap to the top of the bulb. All of this trouble was corrected when the moulded bulb was adopted, because the bulb was moulded with a shoulder, under which the top of the shell fitted.

The method of assembling with plaster was very slow because it required about one-half hour for the plaster to harden sufficiently to be taken out of the mould, and one operator had to use about 100 moulds, so that the floor space required was very great. There were also objections to plaster, on the ground that it had a tendency to absorb moisture, and when in use in moist places there was occasionally a current from one wire to the other wire in the base, which gradually ate away the wire and broke the connections. This led to the adoption of the present method. This involved the assembling of the screw and cap together before placing it on the lamp. This assembling was first done with a sort of vulcanite composition, afterwards with a piece of porcelain, and still later by assembling with molten glass. The operator now picks up the base, and smears into the inner upper edge of the shell a quantity of the basing compound sufficient to fill up the space between the shell and the neck of the lamp. Then she threads one of the leading-in wires through the hole in the cap, and shoves the base down on the lamp, adjusting it by eye so as to

be symmetrical. Then she places it, base up, in a furnace, in which the compound is heated up to melting point so that it adheres firmly to both the base and the lamp. The protruding wires are then cut off, and soldered respectively to the shell and cap. The soldering is done by putting a little soldering paste on the wire where it touches the cap, and holding it up against a thinned pointed rod of copper heated by a gas flame. The method of soldering is practically the same as it was in 1881; that is, it is one of the few operations in which practically no improvement has been made.

So far the visible elements of the lamp have been considered and little or no attention has been paid to three very important processes, viz.: carbonization, exhaustion, and testing.

Our present method of carbonization applied to the bamboo filaments of 1881 would probably not make them any better than they occasionally were, but it would make them all as good as the best. The improvement in carbonization has been mainly in the line of increasing the production, at the same time that it has resulted in a much more uniform product. The important things in the carbonization are to keep the air away from the filaments so that they will not oxodize, and to raise the temperature so slowly that the volatile constituents of the filaments shall not be expelled so rapidly as to cause fractures in their structure.

At first filaments were carbonized in little nickel forms which were nothing more than extremely shallow boxes stacked up one above another in plumbago crucibles, so that each box served as a cover for the one just below it. and each box contained but one filament. Nickel forms did not permit of high enough temperature without being destroyed, and similar carbon forms were soon substituted. Later, when shankless filaments were used, deeper boxes were substituted for the forms, quite a large number of filaments were placed in them, and the boxes were filled with a packing material to keep the filaments in shape.

Squirt filaments at present are packed without forms in cubical crucibles. Fig. 9 shows a bunch of filaments.

A layer of these bunches is placed in the bottom of the crucible and covered over with a packing material, such as sawdust, or similarly finely-ground substances; then successive

layers are put in until the crucible is full. The purpose of the packing material is to hold the filaments in place and shape. Carbonizing results in a cubical block sufficiently tenacious to hold together, but friable enough to be easily broken apart to get out the filaments. It will readily be seen that by the modern method of packing many more filaments can be put in a

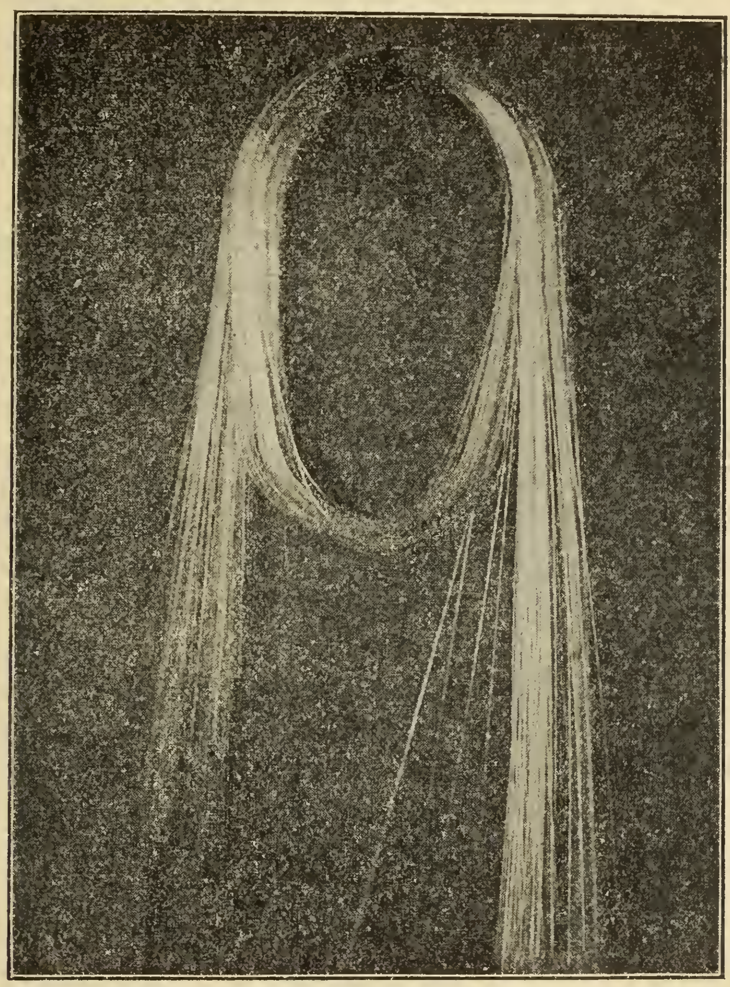

Fig. 9.

crucible than when they were packed in forms, one filament in a form.

At first carbonization was done in a brick furnace, burning coal with artificial draft, but later a preliminary heating was given in a cook stove. Still later gas furnaces were used, one type for the preliminary heat, in which a dull red was obtained, and another for the final heat, which brought the temperature to about the melting point of platinum.

In 1881 and until 1895, all lamps were exhausted on Sprengel pumps, as shown in Fig. 10. Mercury from a reservoir flowed down through a contraction (a) which limited the amount of flow, into the tube (b) which served as a cushion for the dropping mercury, and ran across the tube (c) into the tube (d). This tube, a short distance below (c) was of smaller bore, so that as the mercury came down, it trapped bubbles of air which it carried along to the bottom of the tube, where it escaped. At the joint (e) a phosphorus cup was connected, in which was placed a small quantity of phosphoric amhydride, and at the joint, (f) the top tube of the lamp was inserted. The purpose of the phosphoric anhydride was to absorb water vapors in the lamp. It took from one-quarter of an hour to five hours to exhaust a lamp with such a pump. As good vacuum, and consequently as good lamps can be obtained from a pump of this kind as from any of the more recent pumps, but as a matter of fact, through no fault of the pump, large numbers of poor quality lamps were produced in the early history of lamp manufacture, because there are many details in the process of exhaustion which require most careful attention to produce good results. For quite a number of years after we began the manufacture of lamps we alternately made good and poor lamps without knowing it, and the peculiarity of these poor lamps was that they gave longer life than the good lamps. This was because the condition of the vacuum was such that it changed in the early life of the lamp, and reduced the candle-power of the

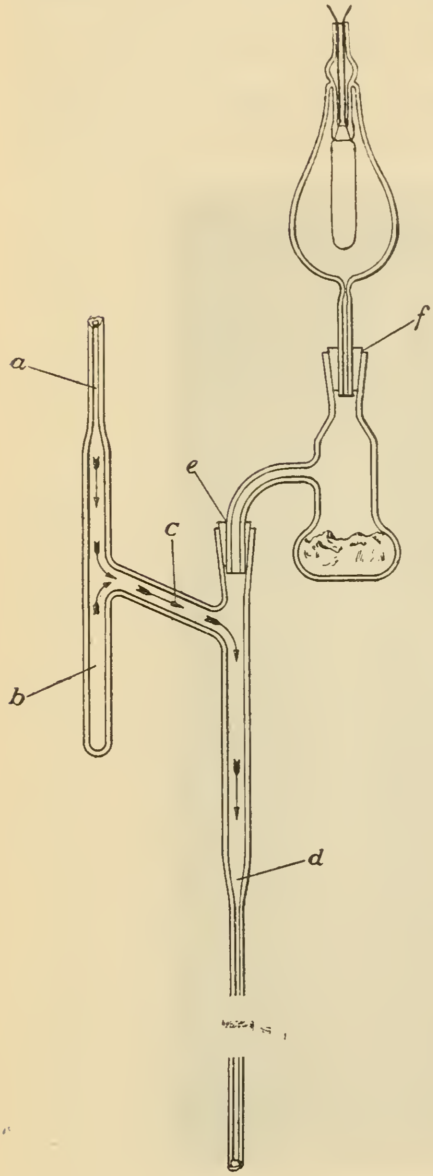

Fig. 10.

filament very, much below the initial candle-power. At this low candle-power the filament could burn a very long time without being destroyed.

The use of mercury produced unsanitary conditions. Pumps were continually breaking, the mercury was spilled on the floor. In warm weather the air of the room was saturated with mercury, and the men after a time became chronically ill with it.

Mechanical pumps were tried from time to time, but were not adopted until an Italian, named Malignanni, discovered that by introducing the vapor of red phosphorus into the lamp at just the right time in the exhaustion, a good vacuum was obtained by the combination of the phosphorus with the residual vapors in the lamp. The red phosphorus, previous to tubulating, was painted on the inside of the top tube, and when the vacum was at the right stage, the lamp was shut off from the pump, and the tube heated on the outside to vaporize the phosphorous, which then spread out in the lamp. The right stage of vacuum for the introduction of the phosphorus was indicated by the condition of a blue halo which appeared in the lamp when lighted to the right degree of incandescence while on the pumps, and the proper combination of the phosphorous and residual vapors showing that the vacuum had been obtained was indicated by the total disappearance of this halo. At this stage the little contraction where the top tube is joined to the bulb was melted off with a torch, and the lamp as a lighting device was practically finished.

By the old mercury exhaust a gang of four men attended to about 100 lamps. With the red phosphorus exhaust each operator has a pump and, exhausting one lamp at a time, can give each lamp the individual attention it requires to give the best results.

It is rather a remarkable fact that the red phosphorus method of exhaustion is not applicable to lamps of less than 30 volts, and these lamps, while exhausted on the same kind of mechanical pump as is used with the red phosphorus, require about ten minutes for the exhaustion.

All lamps after exhaustion are tested for vacuum on an induction coil. If the vacuum is not good,Crookes tube effects are produced.

The early method of testing a lamp for volts consists in putting it on a photometer with a rheostat connected in series with it, and a volt meter connected around it, bringing it to 16 candle-power by means of the rheostat, and reading the meter. To get accurate results a very constant source of current was necessary, and this was obtained by hand regulation of the field magnets of the generator. The man who regulated the voltage was placed near the photometer, and called out whenever the voltage was wrong, so that readings should not be taken at that instant.

A photometer whose accuracy did not depend on the voltage of the circuit being right was put in use about 1885. This is what is called the Sliding Scale Photometer, and is still in general use.This photometer is wired up with the lamps at each end of the bar in multiple, so that both have the same voltage over them, and the voltage of the lamp to be tested is determined by the position of the screen on the bar when in balance.

The calibration of the volt scale is made by taking a number of lamps previously tested on a standard photometer, and selected for each voltage from, say 100 to 120 volts, selecting a lamp of about the middle of this range for a standard to be used permanently at one end of the photometer, and placing the other lamps in turn on the other end of the photometer, moving the screen to a position of balance, and marking on the scale opposite these positions the corresponding voltages of the lamp. The principal advantage of this photometer is that fluctuations in line voltage do not affect its accuracy, because they affect both lamps in the same proportion, and do not alter the position of balance. The production is also increased through not having to read volt meters and indicators.

Perhaps the element which has contributed as much to the improvement of the lamp as any other is inspection. Inspections have been gradually instituted all along the line of manufacture, so that at present we make from first to last fifteen (15) inspections, in each of which from five to six defects are sought for.

Fig. 11 is a table showing the change in the life of the lamp coincident with changes in its elements and the method of its manufacture. The later improvements, corresponding to different periods, were obtained, not by elemental changes in the

lamp, but by a very gradual improvement in the processes. When the importance of maintenance of candle-power began to be appreciated, it was necessary to decide at what per centage of its initial candle-power a lamp was no longer useful and would better be taken down and destroyed rather than be allowed to burn longer. This point has by common consent come to be fixed at 80 per cent. of the initial candle-power.

It will be noted from Fig. 11 that for the earlier lamps the life to 80 per cent. was not given. This is because we did not know the importance of ascertaining this factor, and did not suppose it was anything like so great as we afterwards found it to be. It will also be seen that as the life to 80 per cent. first began to increase, it was accompanied by a very decided decrease in the actual life. The previous long life, as heretofore explained, was due to the rapid diminution of candle-power,

Type of Filament	Date	Watts per Candle	Actual Life Hours	Life of 8 % of Initial Candles Hours
Plain Bamboo	1881	5.8	3000	
" "	1881	4.66	900	
Asphalted Bamboo	1888	3.1	1000	200
Treated "	1893	3.1	1200	260
" Squirt	1896	3.1	700	370
" "	1900	3.1	750	425
" "	1904	3.1	800	475

Fig. 11

and the consequent low temperature at which the filament burned. The 1896 lamp, although having a very much shorter life than the 1893 lamp, is really a much better lamp because of the longer life to 80 per cent. It has been the practice of the Company from the beginning without any intermission to make life tests on lamps, both regular product and experiments.

In comparing the quality of lamps it is necessary to consider three items: Candle-power, the energy consumed, and the life. Numerous tests have shown the comparative lives of lamps at different efficiencies, and in making comparisons we always

caluclate what the life would be at some given efficiency, say 3.1 Watts per candle-power.

Fig. 12 is a table showing the life we can expect from 16 C.P. lamps of different efficffiiency.

These lamps are all the same quality, and if burned at the same temperature would not vary greatly in life. The very great difference in life is due to the difference in temperature. The 80 Watt lamp has four and a-quarter times the surface of the 32 Watt lamp, and the light per unit of surface, and consequently the temperature is very much less. Without going into a calculation, it will be evident at the usual prices of lamps and electrical energy that the 32 Watt lamp, though taking lit-

Watts	Life to 80% of Initial Candles Hours
32	28
40	132
48	412
56	1000
64	2005
72	3570
80	6125

Fig. 12

tle energy, will not be economical, because of the very short life, and consequent frequent renewals. On the other hand, it will be seen that the 80 Watt lamp, though having a very long life, will not be economical because of the large amount of energy used. Depending upon the cost of the lamps and the cost of electrical energy, the most economical lamp to use under a given set of conditions can be determined, and it is almost certain to lie somewhere between the extremes in Fig. 12. In general, the higher the cost of the electrical energy and the lower the cost of the lamp, the higher the efficiency which should be selected.

The 3.1 W.p.C. lamp at the time of its adoption was of too high an efficiency on account of the short life to 80 per cent. of initial C.P. This was not then appreciated, but it is now.

With the subsequent improvement in quality, the life became quite satisfactory. If some improvement in lamp manufacture should greatly increase the life that a 3.1 W.p.C. lamp can be made to give, it is probable that this improvement would be taken advantage of to make the lamp more efficient rather than to prolong its life.

DISCUSSION.

Mr. Wm. J. Hammer.—I have enjoyed listening to Mr. Marshall's very interesting paper dealing with the improvements in manufacturing process of the Edison incandescent electric lamp from 1881 to 1905, and one fact struck me as of extraordinary significance. Mr. Marshall said, with the possible exception of the anchoring wire which might even be excluded from consideration, that the Edison lamp of to-day embodies every feature of the lamp of 1881. He might even go back as far as 1879, for Edison's lamp of that year embodied every essential feature to constitute a successful and commercial incandescent electric lamp; *i. e.*, a high resistance filament of carbon hermetically sealed in an all-glass receptacle, with platinum leading-in wires passing through the glass. No fundamental principle has been done away with and no new principle added thereto, naught save refinements or improvements in manufacturing details. This is truly extraordinary! Where in the world could we find another inventor of which this could be said with equal force. Where could we find in the arts an invention of so great utility, so widespread in its application which has stood for twenty-five years without a single important change in principle, or salient feature of construction. This, it seems to me, bears splendid testimony to the remarkable genius of Edison and the skill and practicability of himself and those about him at Menio Park, New Jersey. Interesting as Mr. Marshall's paper is in dealing with the Edison lamp subsequent to the year 1881, I wish that it had been possible to have embodied a resumé of the earlier work, say from 1878 to and including 1881. I am sure you would all have found much of fascinating interest. When I found this afternoon that I should be able to run over from New York to attend this meeting, it occurred to me to bring along a large photograph of

my historical collection of Incandescent Electric Lamps, which I exhibited at the recent International Exposition at St. Louis, where it received a Grand Prize, and at the suggestion of Dr. Wahl and Mr. Marshall, this photograph has been hung on this board, where it can be examined later, and I shall be pleased to explain certain of the details to those who care to remain. It represents "The History of An Art," and embraces about one hundred types of lamps, showing the entire development of the Edison lamp from its incipient stages up to the present day, and also the work of the various contemporaneous workers in this field, both here and abroad. I have been working upon this collection for over twenty-five years, the foreign lamps having been collected during sojourns in Europe, embracing about seven years' time.

Mr. Marshall speaks of the treating of the filaments of the Edison lamp as having first been employed in 1892. In this connection I might state that I have both lamps and separate filaments which were treated with hydrocarbon vapors (napthalene and gasolene) in the year 1880, at Menlo Park, N. J. They are of both the paper and bamboo types of filaments. One other point mentioned by Mr. Marshall which I think might be modified, is that in which he speaks of the falling off of efficiency in the lamp which he says was not appreciated until a comparatively recent date. I had charge of the early life and efficiency tests and records at the Edison Laboratory, and at the first lamp factory at Menlo Park, and remember that to a considerable extent we did understand that there was a falling off in efficiency. The lamps were frequently re-tested and in connection with my records I made a rack containing ten lamps, showing varying degrees of deposit in the globe and each lamp was compared with these standards as one of many tests, and as the filament disintegrated the deposit grew darker, and this was especially noticable in the old copper-clamp lamps. Our photometer, colorimeter and other tests enabled us to know that there was a falling off of efficiency, but the importance of this was naturally appreciated to a greater degree as our knowledge of the art progressed.

Mr. Marshall.—I agree with Mr. Hammer that a resumé of the earlier work done in developing the Edison incandescent electric lamp would be very fascinating. I have already given

my reason for its omission from this paper. The subject is well worthy of separate consideration, which I trust may yet be given it. I know of no one better qualified to treat the subject than Mr. Hammer, because he was with Mr. Edison when the work was done, and participated in it.

Regarding the adoption of treated filaments in 1892, this has reference to the use of them for commercial lamps. I made life tests of treated filaments as early as 1881, and personally treated filaments long before 1892, but it was until then that practically all our lamps were made from such filaments. Our competitors used them before we did because they owned the patents.

Regarding our knowledge of the falling off in the efficiency of lamps during life, I did not mean to convey the impression that we did not know there was such a falling off. The blackening of the bulb, and the decrease in C.P. was observed before 1881, and our life test records sometimes included a statement of the condition of the bulb as compared with the rack to which Mr. Hammer alludes, but for years our life tests did not always include readings at regular intervals for C.P. at initial voltage, and we did not know how much this falling off in C.P. was affected by variations in the processes of manufacture. Now all life tests do include C.P. readings at regular intervals, and we have a very accurate knowledge of the effects of variations in manufacturing methods.

Prof. G. A. Hoadley.—I have seen the statement that nickel-steel of a certain high percentage of nickel has the same coefficient of expansion as glass. This will allow it to be used in the seal of incandescent lamps instead of platinum and would make a desirable reduction in the price of platinum for other purposes. Can you give us any information on the results of the use of nickel-steel for the purpose?

Mr. Marshall.—Nickel-steel wire can be made having the same coefficient of expansion as glass, but a coating of oxide forms on its surface in the usual method of sealing it into the glass, and air will slowly leak through this oxide. There is a wire specially made for use in incandescent lamps, consisting principally of nickel and steel. The wire becomes black in the process of sealing into the glass, but air-tight lamps can be made with it. There results a small percentage of leaky lamps,

but enough, however, to make it seem unsafe to substitute it for platinum. We have had similar experience with all other attempted substitutes for platinum that we have tried.

PROF. HOADLEY.—How long can an incandescent lamp be run if it is used in parallel with the lamps under test?

MR. MARSHALL.—Standards for incandescent lamps are usually made of an efficiency of 4W.p.C. Before being standardized they are burned long enough to make out the early rise in C.P. After that they will decline quite uniformly in C.P. at the rate of 1 per cent. in about 100 hours. It is not customary, however, to use these standardized lamps continuously on the photometer. A suitable unstandardized lamp is placed on the photometer as a working standard. A standardized lamp is placed on the other end, and brought to the proper voltage. Then the working standard is adjusted to read correctly the candles of the standardized lamps. Several standardized lamps are used in turn to check one another, and in practice are used but a few minutes a day, and will consequently last a long time. The working standard is checked several times a day by putting the standardized lamps on the working end of the photometer to see if they are correctly read by the working standard, but several days usually elapse before any readjustment of the working standard becomes necessary.

PROF. HOADLEY.—If the life test of an incandescent lamp is made at a higher voltage and candle-power than the normal, in order to shorten the time of the test, how are the results obtained reduced to those that would be obtained under normal conditions?

MR. MARSHALL.—The relative lives of lamps at different efficiencies is obtained from empirical curves made from plotting the results of large numbers of the same lot of lamps life-tested at different candle-powers. These curves show that approximately the life varies inversely as the 3.6th power of the candle-power.

PROF. RONDINELLA.—Mr. Marshall has stated that in the early days of incandescent lamps the gradual decrease in a lamp's candle-power was overlooked, and it was rated by its original efficiency in watts-per-candle and its life in hours till the filament broke. Just seventeen years ago I read a paper before the Engineers' Club of Philadelphia on "The Items of

Expense in Incandescent Electric Lighting," based on a consideration of the relation which existed "between these two properties in incandescent lamps," combined with the cost of power. I used a quantity of data showing the *life* averages of Edison lamps for all grades of *efficiency* from 2.5 to 4 watts-per-candle, that had been worked up from the results of several thousand lamps used in regular service during the preceding five years, and I deduced the equation of

$$h = \frac{w^{5.7725}}{3.7349}$$

which expressed the relation between *hours* of life and *watts* per candle in exact accordance with the experimental data, except for lamps of less than 100 hours' life. This equation was then compared with the results obtained from the six other makes of lamps tested by the Franklin Institute after its Electrical Exposition of 1884, and found to agree very closely with them also. I should like to ask Mr. Marshall whether the changes in the process of manufacture have altered this relation between life and efficiency in incandescent lamps, or is it probable that the same formula still maintains?

MR. MARSHALL.—I don't think that the relation between life and efficiency in incandescent lamps is any different now than it was twenty years ago due to changes in the process of lamp manufacture. For instance: In Fig. 12 a 48 Watt lamp, corresponding to 16 candles, 3 W.p.C., will have a life of 412 hours. The 64 Watt lamp, corresponding to 16 candles, 4 W.p.C., has a life of 2005 hours. That is, the 64 Watt lamp is practically five times the life of the 48 Watt lamp. Twenty years ago the life of both of these lamps would have been much shorter, but even so, the life of the 64 Watt lamp would be five times the life of the 48 Watt lamp.

RED BERYL represents a new mineralogical anomaly. The crystals are small but distinct; they are colored by some manganese compound, and are found near Simpson Springs, Utah., in the Dugway range. The matrix is rhyolite, and topaz, bixbyite and altered garnets are associated. W. F. Hillebrand is sponsor for this chromatic novelty.

A NEW AND SIMPLE WELSBACH LAMP.

Quite recently there has been introduced in France and Germany a new form of portable lamp, as compact and light as an ordinary kerosene lamp and more easily operated, which has for a fuel supply wood alcohol.

The burner, as compact as the usual kerosene burner, and adapted to fit any regular fount, is of a novel regenerative type, to which the wood alcohol is conducted by a wick. The latter needs no trimming, as the alcohol by the heat is gasified, and then being mixed with air, produces an intense flameless heat above, which renders brilliantly incandescent the usual netted Welsbach mantle, suspended from above and inclosed in a cylindrical slender glass chimney similar to the student lamp type.

This gives in very small compass an intense illumination, equal to forty-five candle-power with the small mantle, and a smokeless light of remarkable steadiness and brilliancy, and which can be perfectly regulated, with the advantage of being odorless even when lowered to bare incandescence.

One of the points of novelty is an automatic device for feeding a minute quantity of alcohol from the fount to the burner in starting, which is done much in the same way as the usual mechanical extinguishing devices are operated on kerosene lamps. The small amount of alcohol thus brought up is simply ignited by a match, as in an ordinary lamp. In about a minute the light burns brilliantly.

On the Continent, where alcohol is made cheaply, a source of illumination is produced fully as economical as kerosene, and much more easily handled.

It has been stated that in this country it is possible to produce wood alcohol more economically than in Europe, because of our large forests, which form an abundant source of supply of wood.

As a light for photographic and projection purposes, it becomes very efficient, inexpensive and convenient.—*Scientific American.*

LIMIT OF SPEED OF THE AUTOMOBILE.

A prominent French automobile engineer recently stated that it would not be possible for a modern racing automobile to exceed the speed of 130 miles an hour while it is maintained at the present weight. M. Serpollet, the designer of the well-known steam car of that name, has therefore decided to approach this maximum as near as possible during this year. He is now constructing a steam car which he is confident will accomplish the kilometer in 18 seconds, or at an average speed of 125 miles an hour. The motor will develop over 200 horse-power, and the weight of the engine without the steam generator or boiler will be only 150 kilogrammes (330 pounds).

A CHOKE-COIL, or a choker, is a coil of many heavy turns, and may be used as a lightning arrester on the theory that a coiled conductor presents more resistance in the case of a current of high frequency of variation than in one of relatively low frequency.

(Stated Meeting, held Thursday, December 8, 1904.)

Electrical Waves and the Behavior of Long-Distance Transmission in Lines.

BY W. S. FRANKLIN, Director Dept. of Physics, Lehigh University,
Member of the Institute.

[This paper develops Maxwell's mechanical conceptions of electromagnetism and applies them in a very simple and direct way to the discussion of electromagnetic waves.

This fundamental discussion of electromagnetic waves is followed by a discussion of wave distortion on telephone lines. The effect of line resistance and line leakage upon wave distortion is explained and a very elementary statement is given of the reduction of line losses (in pure wave transmission) by the increase of line inductance.—THE EDITOR.]

In the discussion of any class of physical phenomena the choice lies between two methods, one making use of conceptions, generally mechanical conceptions, and the other employing elaborate mathematical developments, usually based upon differential equations. The present purpose is to describe in popular but precise terms, the phenomena of electric waves and especially to give an intelligible account of electric wave distortion. For this purpose the purely mathematical method is utterly hopeless and unfortunately the conceptual method is nearly hopeless also for the reason that the conceptions which one must employ in describing electromagnetic actions are not only unfamiliar but they are, to a great extent, antagonistic to those more or less indefinite but extremely persistent mechanical notions which underlie nearly every one's idea of electricity.

In this discussion I shall make use of Maxwell's cellular theory of the ether and I assure you that you need not concern yourselves with the limitations of this theory. It is more than adequate to our present purpose. I shall devote a large part of the time at my disposal in developing the conceptions of electromagnetic action which are based upon Maxwell's idea of a cellular ether, and in this discussion you are to understand that I am not contending for the truth of these conceptions, I am only insisting on their utility.

Fundamental Conception.—The ether is to be considered as built up of very small cells of two kinds, positive and negative,

in such a way that only unlike cells are in contact. These cells are imagined to be so connected, where they are in contact. that if a cell be turned while the adjacent cells are kept stationary, then a torque, due to elastic reaction of adjoining cells, is brought to bear upon the turned cell, which tends to right it, and which is proportional to the angle turned.

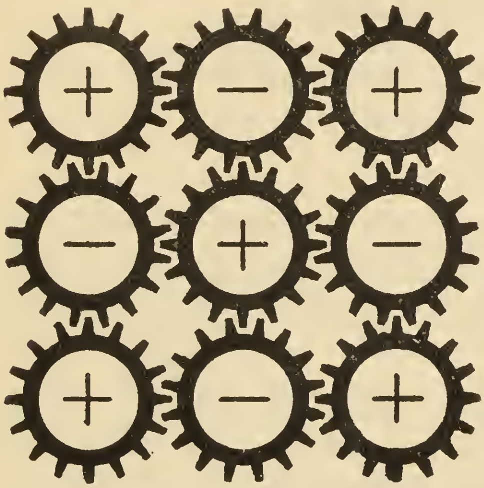

Fig. 1.

For example, the ether cells may be thought of as small cog wheels with rubber teeth, positive cells and negative cells gearing into each other, as shown in Fig. 1. In subsequent figures these cog wheels are represented by plain circles.

Conception of the Magnetic Field.—The ether cells at a point in a magnetic field are to be thought of as rotating about axes which are parallel to the direction of the field at the point, the angular velocitiy of the cells being proportional to the intensity of the field at the point. The positive cells rotate in the direction in which a right-handed screw would be turned that it might move in the direction of the field, and the negative cells

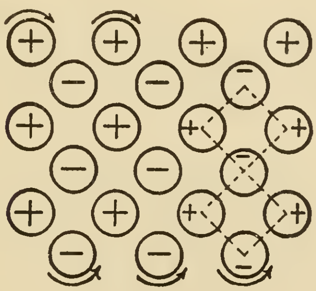

Fig. 2.

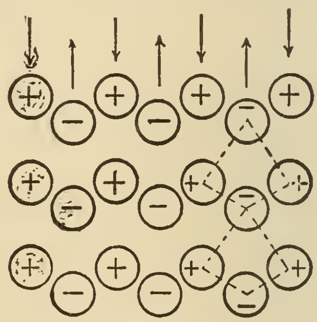

Fig. 3.

rotate in the opposite direction. This opposite rotation of positive and negative cells is mechanically possible since only unlike cells are geared together.

This rotatory motion of the ether cells is indicated in Fig. 2, which represents a magnetic field perpendicular to the plane of the paper, and directed away from the reader; all the positive

cells rotate clockwise, and the negative cells counter-clockwise. The kinetic energy per unit volume in such a system of rotating cells is proportional to the square of the angular velocity, which is consistent with the fact that the energy (kinetic) per unit volume in a magnetic field is proportional to the square of the intensity of the field.

Conception of the Electric Field.—The positive ether cells at a point in an electric field are to be thought of as displaced in the direction of the field, while the negative cells are displaced in the opposite direction; this displacement being proportional to the field intensity. Thus Fig. 3 represents the case in which the positive cells have been displaced towards the bottom of the page relatively to the negative cells. Fig. 4 represents two

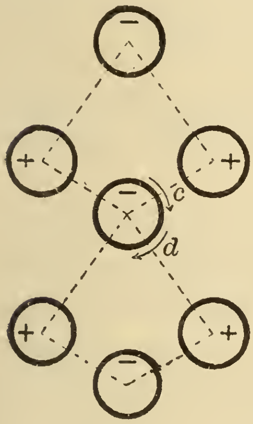

Fig. 4.

Fig 5.

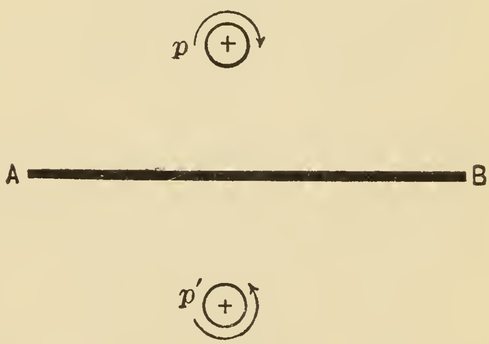

Fig. 6.

meshes. The downward displacement of the positive cells has distorted these meshes, which are normally square. Since this cell structure of the ether is assumed to be elastic, its distortion, as represented in Figs. 3 and 4, represents potential energy. The amount of potential energy per unit volume is proportional to the square of the displacement. This is consistent with the fact that the energy (potential) per unit volume in an electric field is proportional to the square of the field intensity.

The two positive cells to the right of the middle cell in Fig. 4 being displaced downwards, may be conceived to exert troques upon the middle cell, as shown by the arrows *c* and *d*; which troques are proportional to the intensity of the electric field,

i. e., to the displacements of the cells. The cells to the left exert equal but opposite troques upon the middle cell. This troque action which accompanies the distortion of the cell structure of the ether is the connecting link between electric field and magnetic field, and it is the basis of the mechanical conception of electro magnetic action.

The Energy Stream in the Electromagnetic Field.—A region in which electric field and magnetic field coexist is called an electro-magnetic field. It has been shown by J. H. Poynting that energy streams through an electromagnetic field in a direction which is at right angles both to the electric field and to the magnetic field at each point, and that the amount of energy per second which streams across one square centimeter of area is proportional to the product of the electric and magnetic field intensities. In case the electric and magnetic fields are not at right angles to each other the energy stream is proportional to the product of the intensities of the two fields into the sine of the included angle.

Explanation of Energy Stream.—Consider three gear wheels, A, B and C, Fig. 5. Let A and C exert equal and opposite torque actions upon B. Then, if the wheels are turned, work will be transmitted from A to C, or from C to A, according to direction of turning and to direction of troque action, and the rate of transmission of work will be proportional to the product of troque action into speed.

Imagine the cells in Fig. 3 to be rotating, positive cells in one direction, negative in the other, about axes perpendicular to the paper. This constitutes a magnetic field perpendicular to the electric field, which is towards the bottom of the page. On account of the troque actions between the cells, as before explained, energy will be transferred to the right (or left) by each chain of geared cells at a rate which is proportional to the product of the intensity of the magnetic field into the intensity of the electric field, and the energy per second flowing across an area perpendicular to both electric field and magnetic field is proportional to the product of the respective field intensities into the area; for this area is proportional to the number of rows of cells which are acting as chains of gear wheels. The energy stream, that is, energy per unit area per second, is there-

fore proportional to the product of magnetic and electric field intensities, and is at right angles to both.

The Electric Current.—Consider a wire, AB, Fig. 6, along which an electric current is flowing. The magnetic field on opposite sides of AB is in opposite directions, so that positive ether cells at p and p^1 are rotating in opposite directions, as shown. Since an electric current may be maintained for an indefinite time, this opposite rotation of positive ether cells on the two sides of AB cannot be due to an ever-increasing ether distortion (the cells are geared together, as it were), but there must be a slip between adjacent cells somewhere between p and p^1. This slip between adjacent ether cells takes place in the material of the wire, and constitutes the electric current.

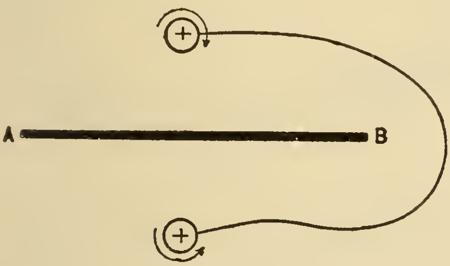

Fig. 7.

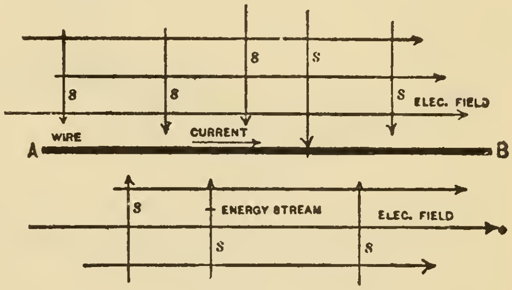

Fig. 8.

Steady electric currents flow in closed circuits. Let AB, Fig. 7, be a wire carrying a steady electric current. If this wire does not form a closed circuit, the opposite rotations of like ether cells on opposite sides of AB cannot continue without adjacent cells slipping on each other somewhere along any chain of cells passing around the end of AB. That is, lines of steady slip of the ether cells are necessarily closed lines. When a current does flow in a circuit which is not closed, and increasing ether distortion (electric field) is produced around the end portions of the circuit, which produces (constitutes) electric charge there, as explained later.

Flow of Energy in the Neighborhood of an Electric Current.—Let Fig. 8 represent the neighborhood of a long wire, AB, through which electric current is flowing. The electric field in the neighborhood is parallel to the wire, and the magnetic field circles around the wire. The product of magnetic field intensity into electric field intensity is the energy stream, and this is directed towards the wire from all sides. This energy stream-

ing in upon the wire changes into heat which appears in the wire. In case the wire is of high resistance, the electric field (volts per centimeter) is of great intensity, and, for a given current (given intensity of magnetic field) the energy stream is correspondingly intense, making the wire very hot. The electric field is not everywhere perpendicular to the wire, especially near the battery or dynamo which is maintaining the current. The energy therefore streams out from the battery or dynamo through the whole region surrounding the wires, and the energy stream turns in upon the wire throughout its length.

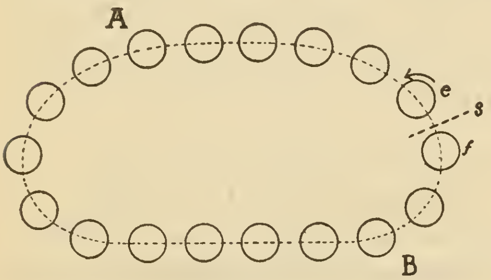

Fig. 9.

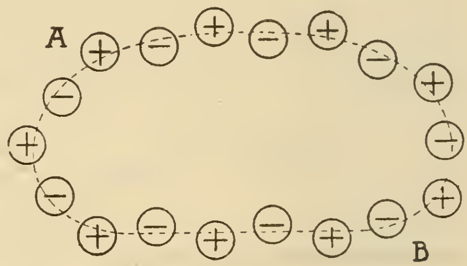

Fig. 10.

The Charge on a Condenser and Its Disappearance when the Condenser Plates are Connected by a Wire.—Consider a closed chain of gear wheels, AB, Fig. 9. If the gears are allowed to slip at any point, *s*, the gear *f* being held stationary and the gear *e* turned in the direction of the arrow, then the chain of gears will be distorted, as shown in Fig. 10. Conversely, a chain of geared wheels, which by elastic action tend to stand in a row,* will be relieved from such a zig-zag distortion, as shown in Fig. 10 by permitting the gears to slip anywhere along the chain and the potential energy stored in the distorted chain will be geared towards the place where slipping takes place.

Let A and B, Fig. 11, be two metal plates and let each dotted line represent a closed chain of ether cells, like Fig. 9. An electric current forced through the wire means the forced slipping of ether cells all along the wire and each chain of the cells, initially like Fig. 9, becomes distorted like Fig. 10.

*The chains of positive and negative ether cells are thought of as standing in zigzag rows when undistorted, as shown by the horizontal rows in Figs. 2 and 3. Hereafter the chains of cells are to be thought of as straight (or uniformly curved) when free from distortion, in order that the diagrams may be simpler.

Throughout the region between A and B the positive ether cells receive an upward displacement and the negative cells receive a downward displacement, that is, this region becomes an electric field and the plates A and B become oppositely charged.

If the charged plates are now connected by a wire, as shown in Fig. 11, each closed chain of geared cells is cut by the wire, slipping begins all along the wire and the energy of each distorted chain of cells is transmitted along the chain, flowing into the wire as indicated by the arrows in the figure.

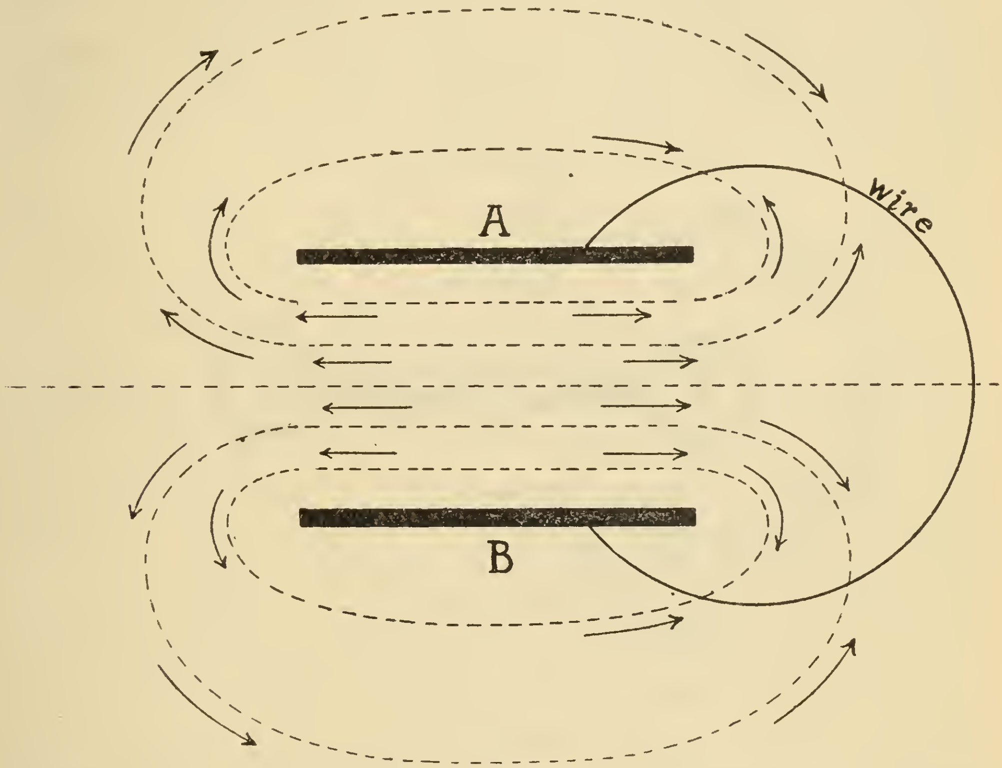

Fig. 11.

An electric spark is a line of slip produced by the breaking down of the mechanism which sustains the electric stress, and the electric energy flows in upon a spark as it does upon a wire carrying current.

The Electric Oscillator.—Let AB, Fig. 12, be the balls of the oscilator upon which electric charge has been collecting. Consider a chain of cells which, when undistorted, lies along a dotted line, which is everywhere perpendicular to the lines of force of the electric field. When A is positively charged, this chain is distorted as shown(in part), but since it is a closed chain,

this distortion is fixed. When a spark occurs at the gap, a line of slip is established across this chain, and the distortion disappears as above explained.

If the slip takes place with great friction (high electrical resistance in the gap), the cells at the spark begin turning slowly, and the entire energy of the electric field is geared into the gap and changed to heat. If the slip is almost frictionless (low electrical resistance), the electrical energy is used mostly in overcoming the inertia of the cells as they are set rotating, and after a very short interval of time a very large part of the electrical energy will have been converted in kinetic energy of the rotating cells (magnetic energy). During this conversion,

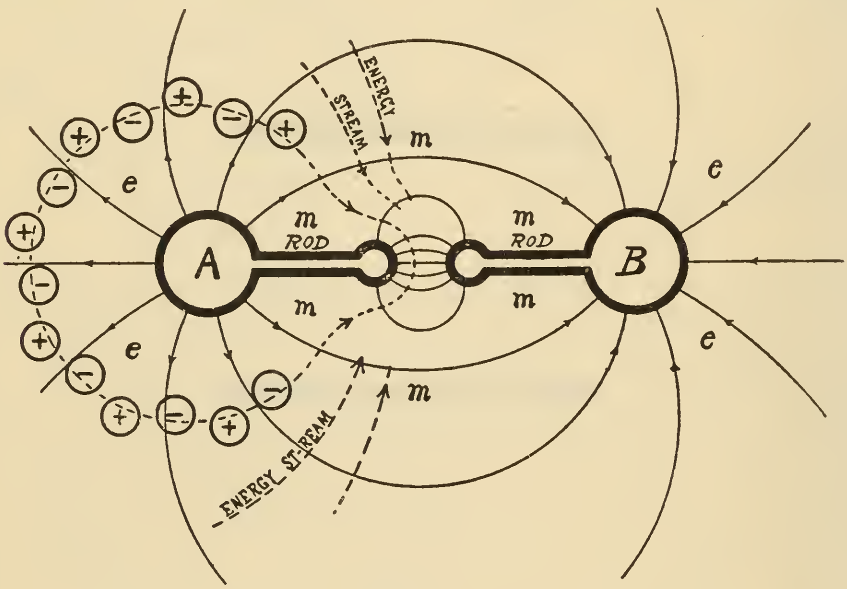

Fig. 12.

energy, streaming along the dotted lines, largely disappears from the regions *ee*, and is distributed mainly in the region *mm*. When the chain of cells has been freed from distortion, the rotatory motion of the cells between A and B will have reached a maximum, and on account of their momenta the cells will continue turning and produce a distortion of the chain in a reversed sense. At the same time the energy will, to a large extent, stream back from the region *mm* to the region *ee*, the ball A will be negatively charged, and the ball B will be positively charged. The reversed distortion of the chain of cells is then relieved by a reversed slip (a reversed current in the rods and gap), and so on.

These oscillatory changes take place so rapidly that the portions of the distorted ether which are remote from AB do not follow the changes promptly. This gives rise to electrical waves.

The Electromagnetic Wave.—Before describing the electromagnetic wave, it will be instructive to consider a common property of all wave motion. Take, for example, a wave traveling over the surface of water. This wave consists of a moving hill of water, and a given particle of water is set in motion when the wave reaches it and comes immediately to rest when the wave has passed by. What is it that supports the hill of water and where is the unbalanced force which causes the water to gain velocity and then lose it again as the wave passes by? The fact is that a wave always consists of two elements, a local distortion of the medium and a local acceleration of the medium and the forces which are associated with the distortion are precisely the forces which produce the acceleration. The distortion sustains the acceleration, as it were, and the acceleration sustains the distortion as they both travel along together. The two are mutually dependent. Everyone knows, furthermore, that to lift an oar from the water leaving a depression, produces two waves, one traveling forwards and the other backwards, and that each of these waves has a motional phase and a distortional phase, although the original disturbance was a depression (distortion) pure and simple, without any motional phase. Similarly, a sharp blow on a long stretched wire imparts motion to a short portion of the wire, and this motion quickly generates two oppositely moving waves each having a motional phase and a distortional phase, although the original disturbance consisted of motion only.

An electromagnetic wave also consists of a state of distortion and a state of motion traveling along together and mutually sustaining each other. The distortion is electric field and the motion is magnetic field. A layer of electric field unsustained breaks up into two electromagnetic waves just as an unsustained bend in a stretched wire breaks up into two waves, and a layer of magnetic field unsustained breaks up into two oppositely-moving electromagnetic waves just as a local state of motion of a wire produced by a hammer blow breaks up into two waves.

Some detailed ideas of the constitution of an electromagnetic wave may be obtained with the help of Fig. 13, in which the fine arrow lines represent the lines of force of a layer of electric field and the fine dots represents the lines of force of a layer of magnetic field directed towards the reader. This layer of electric and magnetic field moves to the right and constitutes an electromagnetic wave. The mutual sustaining action of the electric and magnetic field is explained in terms of Maxwell's cellular ether theory as follows: The two wires should be thought of as two broad metal ribbons for the sake of simplicity and they bound the electric wave very much as a speaking tube

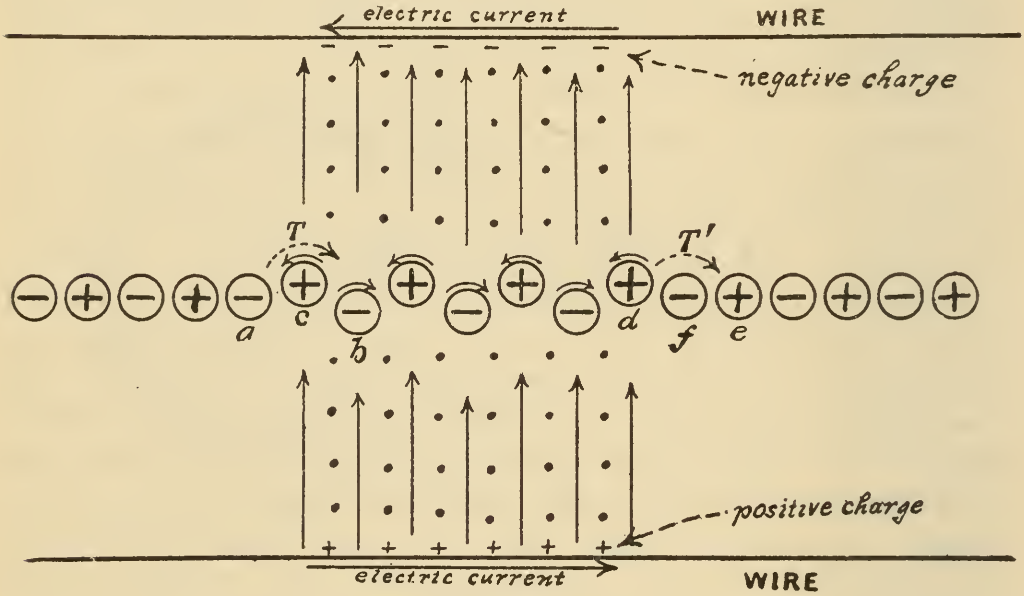

Fig. 13.

bounds a sound wave which passes through it. Midway between the two wires which bound the wave a simple chain of ether cells is indcated in Fig. 13. The part of this chain which lies within the wave is distorted and this distortion represents the electric field. Furthermore, those cells which lie within the wave are rotating as indicated by the small curved arrows, and this rotation represents the magnetic field.

Throughout the middle portions of the wave each rotating cell is acted upon by equal and opposite torques by the adjacent cells ahead of it and behind it, as explained in connection with Fig. 4. Therefore all the cells in the middle portion of the wave rotate at unchanging speed. The cell *d* however, exerts

an unbalanced torque upon cell f as indicated by a dotted arrow T^1 and this torque quickly sets the cell f rotating, while the cell b exerts an unbalanced torque T upon the cell c which quickly stops the rotation of the cell c. Thus the state of motion of the cells between c and f travels to the right. Likewise the state of distortion travels to the right inasmuch as this state of distortion is inseparably associated with the torque actions just referred to.

The terminating of the electric lines of force at the wires which bound the wave constitutes electric charges, positive on one wire and negative on the other, and electric currents flow along the two wires within the space occupied by the wave. This electric current flows in one direction in one wire and in the opposite direction in the other wire. The necessity for this current flow is involved in the bounding of the wave by the metal wires or ribbons, inasmuch as the rotation of the ether cells on one side of the ribbon with stationary ether cells on the other side, requires slipping of adjacent cells in the material of the ribbon.

The mutual dependence of the moving electric and magnetic fields which together constitute an electromagnetic wave may be expressed in terms more or less familiar. Before attempting this, however, it may be well to state that the fundamental relation between force and acceleration in mechanics *is in electromagnetic theory the same thing as the relation between electromotive force and changing magnetic flux.* A magnetic field of intensity H moving sidewise at a velocity v produces electromotive force according to the equation $E = l H v$, or in general $E = l \mu H v$ or since E/l is electric field intensity e we may write

$$e = \mu H v \quad (1)$$

in which μ is the magnetic permeability of the medium.

Now, another fact, not generally known among practicing electricians, is that an electric field of intensity e moving sidewise at velocity v produces magnetomotive force F according to the equation $F = l e v$, or in general $F = l k e v$, or, since F/l is magnetic field intensity H, we may write,

$$H = k e v. \quad (2)$$

in which k is the inductivity of the dielectric medium.

The condition which must be satisfied in order that the whole

of *H* may be due to the sidewise motion of *e* and at the same time the whole of *e* due to the sidewise motion of *H*, that is, that *H* and *e* may sustain each other completely, is that equations (1) and (2) be simultaneous equations. Treating equations (1) and (2) therefore as simultaneous equations we have:

$$v = \frac{1}{\sqrt{\mu k}} \qquad (3)$$

and

$$\tfrac{1}{2}\mu H^2 = \tfrac{1}{2} k e^2 \qquad (4)$$

Equation (3) gives the velocity at which *H* and *e* must move sidewise so as to be mutually dependent on each other. This is, of course, the velocity of an electromagnetic wave. Equation (4) expresses the fact in a so-called pure electromagnetic wave the magnetic energy is always and everywhere equal to the electric energy.

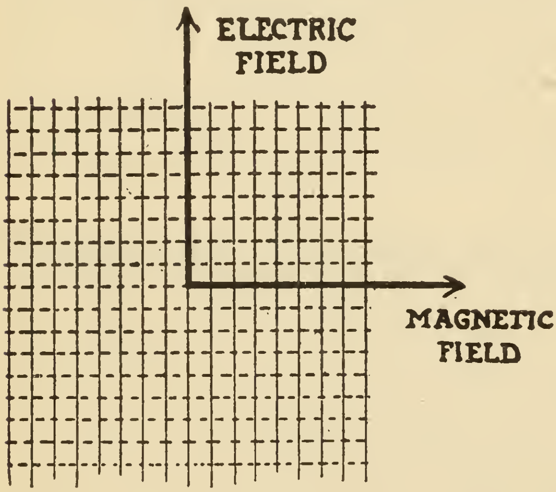

Fig. 14.

Fig. 14 represents a front view of a plane electromagnetic wave approaching the reader. The full lines represent electric lines of force and the dotted lines represent magnetic lines of force.

Wave Distortion.—The distortion of an electromagnetic wave, which is so troublesome in telephonic transmission, is due to the resistance of the wires or ribbons which bound the waves and to the conductivity of the insulating medium between the wires, and a clear understanding of electromagnetic wave distortion depends upon clear ideas of these effects of line resistance and line leakage.

One may see from Fig. 13 that the frictional resistance of the slipping ether cells in the material of the wires (the mechanical analogue of line resistance) causes the angular velocity of the ether cells (the mechanical analogue of magnetic field) to decrease continually. In fact the effect of line resistence is to cause the magnetic field *H* in an advancing electromagnetic

wave to decrease as the wave moves along, while the electric field in an advancing wave is not directly affected by line resistance.

On the other hand, if the structure of the medium in the region occupied by the advancing wave gives way continuously to the ether stress which constitutes the electric field, this ether stress will decrease steadily as the wave advances just as a state of stress in a stretched molasses-candy rope decreases steadily with time. This steady giving way of the ether under stress is the mechanical conception of the conductivity of the insulating medium between the wires, that is of line leakage, and in fact the conductivity of the insulating medium between the wires of a transmission line causes the electric field to die away as the wave moves along, while the magnetic field in an advancing wave is not directly affected by line leakage.

The distortion of an electromagnetic wave pulse as it travels along a transmission line is due wholly to the fact that line resistance reduces magnetic field only and that line leakage reduces electric field only, and a detailed description of wave distortion depends upon a clear understanding of an impure wave, as it is called, that is, a wave in which either the magnetic field has been reduced below the value which is necessary to sustain the electric field or in which the electric field has been reduced below the value which is necessary to sustain the magnetic field.

It has already been pointed out how a local bend in a stretched string which is unsustained by local acceleration breaks up into two oppositely moving pure waves and how a local movement of a stretched string due to a hammer blow breaks up into two oppositely moving pure waves. From this it is not difficult to see that if a wave, originally pure, were to travel along a string which is strung through a viscous liquid, the viscosity of the liquid would cause the motion to die away as the waves travel along but would not directly affect the distortion of the string, and therefore, at each point on the string, that part of the distortion which is sustained by what remains of the motion, travels onward as a pure wave, while that part of the distortion which is not sustained, the excess of distortion as it were, breaks up into two oppositely moving pure waves, one of which merges with what Heaviside calls the head of the

wave, and the other moves backwards and generates what Heaviside calls the tail of the wave.

Fig. 15 shows in an exaggerated way, an electromagnetic wave in which the magnetic field M has been reduced by line resistance, while the electric field E has not been reduced, and

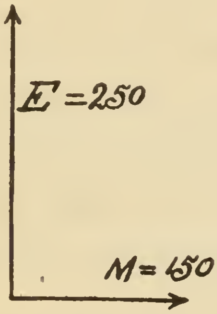

Fig. 15.

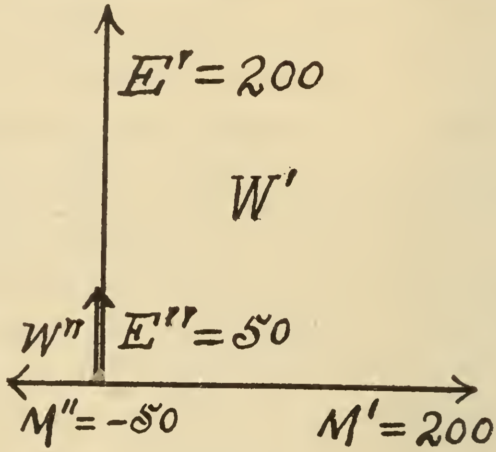

Fig. 16.

Fig. 16 shows the two pure waves W′ (which consists of E′ = 200 and M′ = 200) and W″ (which consists of E″ = 50 and M′ = — 50) into which this so-called impure wave resolves itself. The wave W′ continues to move forward and the wave W″ moves backwards.

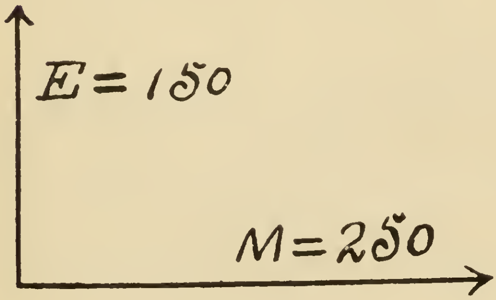

Fig. 17.

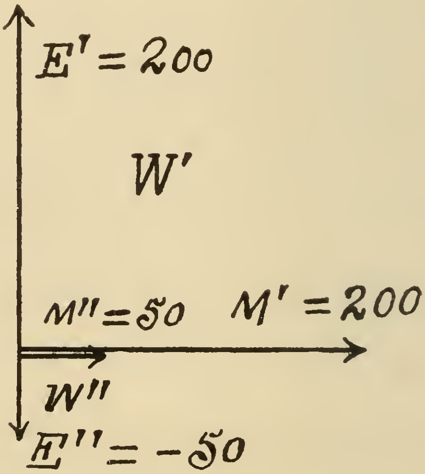

Fig. 18.

Similarly Fig. 17 shows an electromagnetic wave in which the electric field E has been reduced by line leakage, and Fig. 18 shows the two pure waves W′ and W″ into which this impure wave resolves itself.

Before describing the actual process of wave distortion, it is necessary to adopt a scheme for representing an electromagnetic wave pulse graphically. Such a representation is indi-

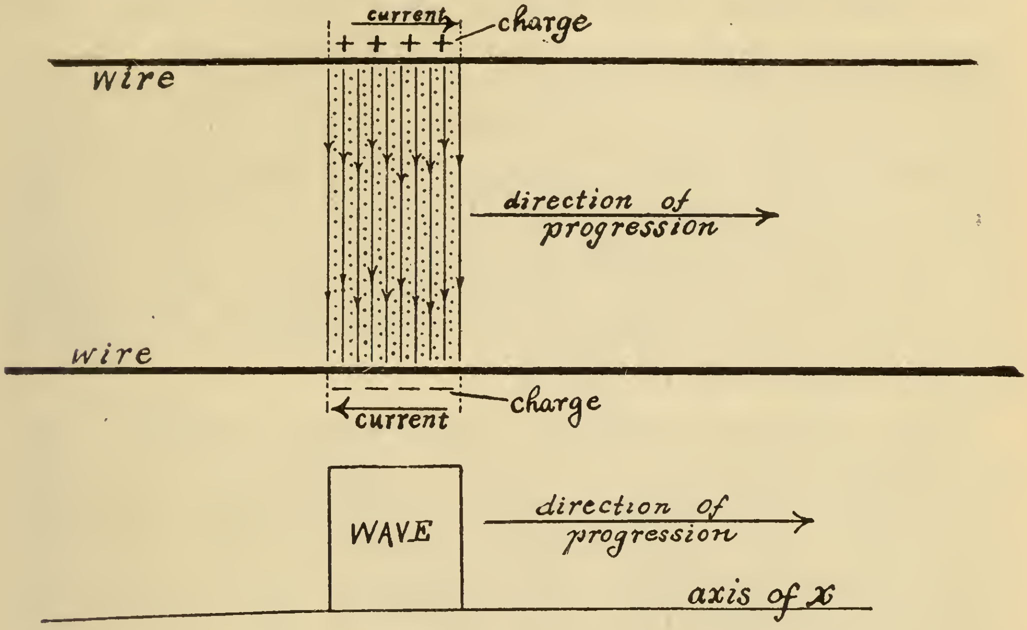

Fig. 19.

cated in Fig. 19. The rectangular curve marked "*wave*" in the lower part of this figure represents the pure wave pulse which is shown directly above it.

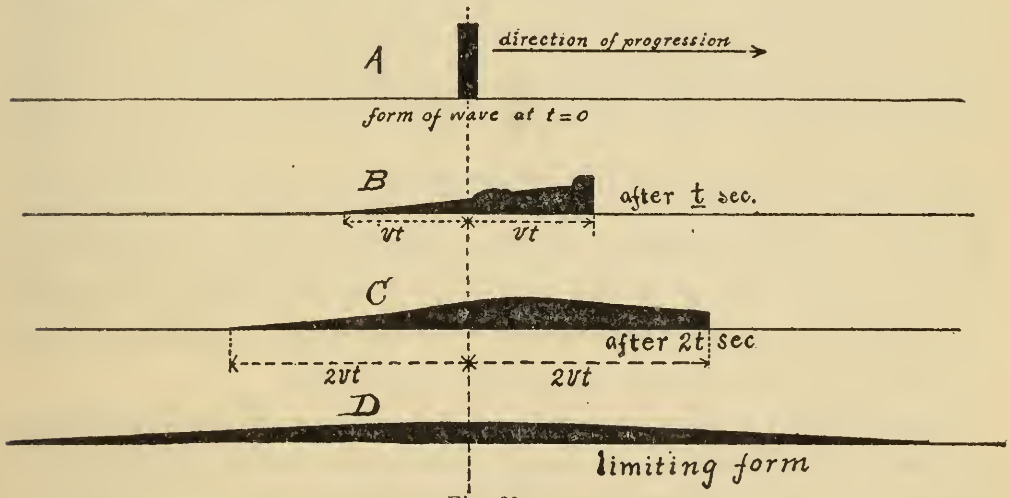

Fig. 20.

The black rectangle A, Fig. 20, represents a pure electromagnetic wave which at a given instant is supposed to be called into existence out on an indefinitely long pair of wires. As this

wave proceeds its magnetic field is decreased by line resistance (or its electric field is decreased by line leakage) and the wave becomes impure. The result is, as before explained, that a portion of the energy of this original wave begins to shoot back ward at every point along the line as a reflected wave. This reflected wave, which is of course in its turn partially re-reflected as it travels backwards, generates the tail of the wave after t seconds is shown by B. The head of this resulting wave has been reduced in values of E and M and the tail reaches to a distance vt back of the original position of the wave. The form of the wave after $2t$ seconds is shown by C and the final limiting form of the wave is shown by D. The fatness of the tail is greatly exaggerated in Fig. 20.

When, during an element of time, an electromagnetic wave has suffered decrements of E and M represented by $\triangle$ E and $\triangle$ M, due to line leakage and line resistance respectively (both E and M being expressed in such units that their numerical value will be equal when $\frac{1}{2}\mu M^2$ is equal to $\frac{1}{2} k E^2$), then the common numerical value of E and M in the reflected wave which shoots out into the tail is $\frac{1}{2}(\triangle E - \triangle M)$ and the residual numerical value common to both E and M in the head of the wave is $E - \frac{1}{2}(\triangle E - \triangle M)$ or $M - \frac{1}{2}(\triangle E - \triangle M)$. The loss of energy in the head of the wave due to line leakage is $k E \triangle E$, the loss of energy in the head of the wave due to line resistance is $\mu M \triangle M$, and the loss of energy from the head due to the spreading into the tail of the wave is $\frac{1}{8}(k+\mu)(\triangle E - \triangle M)^2$. Therefore when $(\triangle E - \triangle M)$ is small the loss of energy from the head of the wave by line leakage and by resistance is vastly larger than the loss of energy by the spreading of energy into the tail. When, however, $(\triangle E - \triangle M)$ is large the loss of energy from the head of the wave by the spreading of energy into the tail is of the same order of magnitude as the loss of energy due to line leakage or to line resistance.

When $(\triangle E - \triangle M)$, in previous section on Wave Distortion, is small the spreading of energy into the tail is negligible in comparison with resistance loss and leakage loss, so that when $(\triangle E - \triangle M)$ is small any increase of line resistance or leakage with a view of still further eliminating wave distortion produces an increased loss of energy from the head of the wave, which

is nearly equal to the increase of resistance loss or leakage loss of energy because when ($\triangle$E—$\triangle$M) is small the loss of energy from the head of the wave is sensibly equal to the sum of the resistance and leakage losses.

On the other hand when ($\triangle$E—$\triangle$M) is large the spreading of energy into the tail is considerable, and any increase of loss resistance or leakage with a view of largely eliminating wave distortion produces of course an increased loss of energy from the head of the wave, but this increased loss from the head of the wave is much less than the increase of resistance loss or leakage loss, because the spreading of energy into the tail of the wave is greatly reduced by the increase of line resistance or line leakage.*

On all ordinary telephone lines and cables the loss of energy due to line resistance exceeds the loss due to line leakage, except perhaps when the line or cable is out of order. Therefore, an increase of line leakage generally reduces wave distortion and increases the distinctness of telephonic transmission. Whether this increase of line leakage is justifiable depends largely upon whether it is constant and independent of the weather, upon the degree of wave distortion, for if the wave distortion is excessive the reduction of useful energy in the head of the wave is by no means equal to the increased loss of energy by leakage, as explained above, and upon the extent to which the diffused energy that follows in the tail of every wave pulse seriously interferes with the distinctness of the telephonic transmission.

Reduction of Line Losses and of Wave Distortion by Increasing Line Induction.—The use of increased inductance for decreasing wave distortion and for decreasing the loss of energy in the

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*A statement was given in the *Electrical Review*, Vol. 46, p. 242, Feb. 11, 1905, in illustration of this tendency to actually conserve the useful energy in a wave pulse by increase of line resistance or line leakage. This statement was, that an increase of the leakage of a perfectly insulated line so as to make the leakage loss equal to the resistance loss results in an increased energy loss from the head of the wave in the ratio of $1\frac{1}{2}$ to 2. This statement is faulty inasmuch as for some inexcusable reason it was based upon the aberrant idea that the energy of a wave is proportional to E (or M) instead of to E^2 (or M^2) as everyone knows.

head of a wave pulse while traveling over a given line may be shown in a very simple and elementary way as follows:

In the first place equations (3) and (4) may be written

$$v = \frac{1}{\sqrt{LC}} \qquad (5)$$

$$\tfrac{1}{2} L i^2 = \tfrac{1}{2} CE^2 \qquad (6)$$

in which L is the inductance of the transmission line per unit length, C is its capacity per unit length, i is the current flowing outward in one line and backward in the other at a given point on the line, and E is the electromotive force between the lines at the given point. The derivation of (5) and (6) from (3) and (4) need not be considered, although it is simple.

Let us consider a special case for the sake of clearness. Suppose a battery of electromotive force E is suddenly connected to the sending end of the line and a moment later disconnected. A rectangular wave of length l would be started along the line. This wave contains a certain amount of energy, a certain portion of which is dissipated or left dangling along the line, and the remainder arrives in the head of the wave at the receiving station. Suppose now that L is quadrupled, C and E being kept unchanged for the sake of comparison. Then from equations (5) and (6) v would be halved and i would be halved. If the sending battery is now connected to the line for the same length of time as before, a rectangular wave of length $\frac{1}{2} l$ will be started along the line, inasmuch as v is halved. Now, current flows in the line wires only where the wires bound the wave, that is in length l of the double line in the first case and in length $\frac{1}{2} l$ of the double line in the second case. Furthermore, the time required for the wave to reach the distant end of the line is twice as great in the second case. Therefore R i^2 t, or the total energy dissipated in the wires from the head of the wave, is one-quarter as great in the second case as in the first, since R is halved, i^2 is quartered, and t is doubled. But the total energy is the wave is half as great in the second case as in the first case, since l is halved and the energy per unit length is unchanged, viz.: ($\frac{1}{2}$ L i^2 + $\frac{1}{2}$ CE^2. Therefore the percentage loss of energy from the head of the wave is halved by quadrupling the line inductance. In this ex-

ample resistance loss alone is considered inasmuch as leakage loss is constant under the assumed conditions. The effect of increasing the inductance of a telephone line, loading the line as it is called, is the same as decreasing its resistance insofar as line losses and wave distortion are concerned, provided we are concerned with pure wave transmission. It must be remembered indeed that equations (4) and (6) apply to pure waves only. As applied to pure waves these equations indicate that for a given line there is a fixed relation between voltage and current. Neither can be changed without changing the other unless the line constants are changed. The inapplicability of equations (4) and (6) in their simple form to an alternating current transmission line is at once evident when we consider that there is no fixed relation between current and voltage on such a line. Alternating current transmission is not pure wave transmission.

The extension of this discussion to waves produced by steadily maintained periodic electromotive forces is beyond the scope of the present lecture, and the limitation of the discussion to the wave pulse is deemed advisable for two reasons,

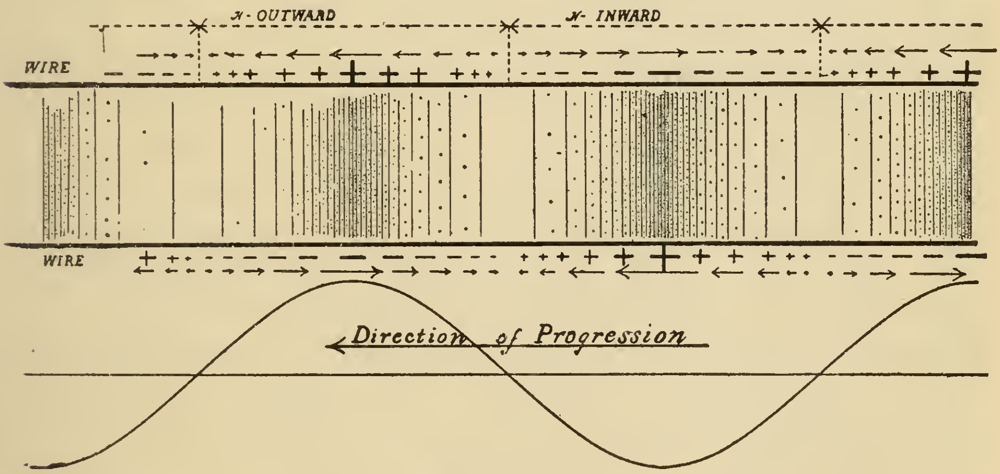

Fig. 21.

+ and — signs represent electric charge on the wires.
The short arrows represent electric current.
Dots represent magnetic lines of force.
Fine lines represent electric lines of force.

E.m.f. between wires at point x equals E Sin $\left(\frac{x}{\gamma}+\frac{t}{\tau}\right)$

Current in one wire at point x equals I Sin $\left(\frac{x}{\gamma}+\frac{t}{\tau}\right)$

viz.: (a) the theory of wave distortion may be completely covered by a consideration of the behavior of a wave pulse, and (b) the physics of wave motion in a medium involving reactions, which in optics gives rise to absorption and dispersion and in electric transmission gives rise to distortion and attenuation, is vastly simpler for the wave pulse than for the wave train. The wave train represents a steady state of a system under the action of a periodic force which has been kept up long enough for the system to settle down to a steady state of motion, and *this steady state depends upon what is taking place at every point in the system,* whereas the wave pulse, the head at any rate, has to do only with what takes place at one single point in the system. The physical nature of a simple electromagnetic wave train is shown in Fig. 21. The curved line at the bottom of the figure is a representation of the wave train.

The reader should keep in mind the fact that all of the discussion as outlined above is based first upon the determination of electromotive force, and current relations on the assumption that line resistance and line leakake are zero, after which line resistance and line leakage are considered as disturbing effects.

It is entirely misleading to the learner to dwell upon the limitations of Maxwell's cellular theory of the ether. There is scarcely a phenomenon of electromagnetic action which is not very greatly simplified by the use of these conceptions. The choice is, as I indicated at the opening of my lecture, between the use of differential equations, not for final integral solutions, but for descriptive purposes, as it were, or the use of mechanical conceptions. In fact, every phase of the foregoing discussion might be easily expressed in differential notations. It is, however, needless to say that such mode of expression would be to a great extent ineffectual. The difficulty with the ordinary mechanical notions which are so fundamentally fixed in electricians' minds, is that they do not give any insight into electromagnetic action, and the difficulty with the cellular theory, aside from the one mentioned by Poynting, is that it may perhaps never give any insight into the phenomena of moving electrons. My advice to the younger readers is to swallow Maxwell's cellular theory and digest it, and do not turn away from it in disgust because some one says, truly, that is does not contain the secret of the universe.

THE FRANKLIN INSTITUTE.

Civic Beauty and Civic Duty.*

By Leslie W. Miller,*

Principal of the School of Industrial Art of the Pennsylvania Museum.

[The author presents in fascinating form the argument for the beautification of our cities from the ethical and aesthetic viewpoint.—The Editor.]

The answer that Pericles made to his critics and opponents when he was blamed for spending so much money in beautifying Athens has been repeated almost in his very words by every public-spirited ruler who has been similarly criticised from that day to this, and it is quite as true to-day as it was twenty-four centuries ago. Unfortunately, too, the necessity for making it arises just about as frequently, and the kind of opposition which Pericles encountered is as active and as determined as it was in his day. It is easy for us to see now that no better use was ever made of public money than was made of that which came in such a golden stream into the coffers of Athens as the head of the Ionic Confederation, and which Pericles spent with such a lavish hand with the single and openly-avowed purpose of making Athens the most beautiful city in the world. He claimed that the works in which this purpose was embodied would confer "eternal honor" upon the city, and that as long as she faithfully performed the duties which devolved upon her by virtue of her leadership among the Grecian commonwealths it was right and proper that she should employ the resources of her position in works that should fittingly signalize and adequately express the leadership which she had so honestly earned and which was so cheerfully accorded her.

It is worth while to pause occasionally in our headlong pursuit of the material and utilitarian aims by which the ideals of

*A lecture delivered before the Franklin Institute, in Association Hall, Friday, January 13, 1905.

to-day are so largely dominated, and to consider what Pericles had in mind and, consequently what it means to care, and to care a great deal, for the mere beauty of things, especially public things, and to note and estimate the part which this regard has played, and must always play, in the life not only of individuals, but of entire communities.

We know now that Pericles was right. Athens has contributed in many ways to the kind of attainment which the world has agreed to hold in the highest honor, but nothing that she ever did has brought her more honor, or done more to assure her the proud position among the cities of the earth which for more than twenty centuries has been accorded her than the pure beauty of the things she built and made.

> "Earth proudly wears the Parthenon
> As the best gem upon her zone,"

and she not only wears this beauty with a kind of pride that is perhaps the only one that is altogether justifiable, she has learned to accept it as the proper, and to a certain extent necessary, expression of most desirable qualities, so that it is impossible to approve the expression without appreciating the quality. All our systems of aesthetics have this in common, that whatever else it is, or is not, beauty is mainly an outward and sensible manifestation of inward perfectness. And while the outward expression may not always argue a corresponding inward perfection, it is at least a reminder of it and a stimulus of effort toward it. We are slowly learning that instead of being an exceptional and exclusive thing, the passion for beauty is among the most fundamental and universal of human instincts, and that the cultivation and direction of this instinct is of the very first importance to the life and health not only of individuals but of communities, of cities and states and nations.

The joy and content of the workman and the devotion and loyalty of the citizen are inseparable from the kind of pride which noble achievement inspires and what is beauty but the simplest and most direct form in which such achievement expresses itself? There can hardly be a more mistaken public economy than that which leads through palpable neglect to inevitable shame. Real leaders have always understood this and

the example of Pericles at Athens is exceptional only in its brilliance. Augustus is remembered not because his armies were successful at Phillippi and at Actium, but because his boast that he found Rome brick and left it marble voiced a sentiment that commands admiring approval wherever society is organized and cities are built. Dante's heart was broken by his exile from Florence, but the burden of the plaint which he made was not so much regret for the loss of his home and family as grief for "the fairest and most renowned daughter of Rome," as he called the city of his birth, whose life he could no longer share. And so of any other city, ancient or modern, to which its inhabitants are genuinely attached; is it not its beauty that they think, and speak, of first? Did anyone ever know a citizen of Venice or of Paris, for example, to emigrate, except under compulsion, or to give any better reason for preferring to stay where he was than the pure beauty of the place itself?

We Americans have something to learn from the experience and example of older countries, and some sins, mainly of omission, to repent of and expiate, but there was never a better sign anywhere than the awakening to the sense of our shortcomings which animates so much present-day discussion, and the energy that is devoting itself, all around us, to the development of civic beauty as at once the expression and the inspiration of civic spirit.

It is encouraging, too, to remember, in spite of so much prevalent misconception on this point, how popular and democratic the most conspicuous movements in the direction of civic embellishment have always been. From Pericles' time to our own, the most beautiful cities have either been free and independent republics or municipalities, or else they were communities whose taste, rather than that of the nominal ruler, determined the treatment which the city received. Probably few monarchs ever cared less either for art or for the people that Louis Napoleon, but he knew how important to his peace of mind it was that Paris should be pleased, and he knew how to please her. As a matter of fact it makes very little difference whether monarchs or burghers rule the cities in name, The cities themselves reflect and express, always and everywhere, only too true sometimes, the temper and the tastes of those whom they shelter.

It is delightful to find this popular responsibility accepted and the popular will expressed as frankly and unequivocally as it was stated in the decree by which the City Council of Florence authorized, in 1298, the reconstruction of the Cathedral "in a style of magnificance which neither the industry nor power of man can surpass, that it may harmonize with the opinion of many wise persons in this city and state, who think that this commune should not engage in any enterprise, unless its intention be to make the result correspond with that noblest sort of heart which is composed of the united will of many citizens," but ordinances of city councils do not often copy this admirable model very closely and the demand of the councillors of the modern city that the best art attainable shall be applied to the service of the public is sometimes, it is true, not so much stated as left to be inferred, but times have changes and councillors have changed with them.

All the great work of the Cathedral builders seems to have been done in much the same spirit as that which the Florentine burghers expressed so well. Probably without exception the splendid structures of the Gothic period are to be regarded as representing not so much the ascendency of the church as the pride of the town in its principal building. This is not the place to trace the reasons for the changes in both religious and civic ideals that have resulted in the decline of the cathedral-building fervor and the diversion into other channels of the energy that was once so largely monopolized by the church, but whether expressed in terms of ecclesiastical magnificence or stately structures of any other kind, the popular purpose and the civic pride which really good public art for the most part represents must not be forgotten.

Let us consider some of the things which share with the church the service which the civic spirit creates, and first the streets. The narrow paths which ran between the rows of huts which served as dwellings for the Greeks, and the dark and crooked alleys in which the cathedral builders lived would not be tolerated a moment in any modern city, but we must not only have streets, we must have open spaces, plazas, playgrounds and parks. It is all very recent, the thought of pleasure-grounds and breathing-places for the use of everybody (the public park, as we know it, hardly existed before 1850), but the

demand for them is very real now. And so of all appliances for transportation and education and justice and all manner of utilities on which the health, comfort and well-being of the inhabitants depend. They played a very small part in the thought of our immediate ancestors compared with the attention which they receive to-day. The duties which they represent are not to be evaded, the only question regarding them relates to the spirit in which they are to be accepted and administered. The great city accepts the duties promptly and treats them not as tasks but as opportunities, but the mean-spirited ones meet them grudgingly as things to be shirked and neglected wherever this is possible. Now, a certain dignity and beauty are inseparable from an adequate and satisfactory administration of these responsibilities. The lessons that are of most abiding value and the memories which are best worth preserving are precisely those which cannot do without the setting which art alone can supply. As the civic spirit develops it learns that the search and service of beauty which we call art is far enough from anything like luxury or indulgence, but that, on the contrary, it stands for, and is the chief reminder and inspirer of, all that is serious and elevated in the life of the community.

REINFORCED concrete is the coming material in modern construction. According to some authorities, it is one of the monumental blunders of this mechanical age that the arches of the New York subway should be made of steel rather than of reinforced concrete.

CHEMICALLY pure iron, produced by electrolysis, has recently been made by Prof. C. F. Burgess, of the University of Wisconsin. The metal is said to be free from all foreign contamination, with the exception of a little hydrogen.

THE composition of the Welsbach mantle has much to do with the effective temperatures in and about the burning zone of gas. The maximum, according to V. Lewes, is reached with 99.9 per cent. thorium oxide, and 0.1 per cent. cerium oxide.

Correspondence.

Fuel Supplies of the Far East and the Possible Consequences to be Anticipated from their Development.

To the Editor:

A note in the Mémoires et *Compte Rendu des Travaux de la Société des Ingéniers Civils de France* (March, 1904), regarding the naphtha in the Extreme-Orient, has much interest in the present conditions of the Russo-Japanese struggle for supremacy in that region. The note referred to, represents oriental Asia as one of the richest parts of the globe in mineral combustibles. The area in Europe of all the coal basins under exploitation is an aggregate in round numbers of about 23,000 square miles, an area equal to only that of the Russian Province of Kasan alone. The extent of the coal deposits in oriental Asia, although they have received up to the present time but little attention, may be considered as incalculable. In addition to these deposits, that country possesses subterranean lakes of naphtha which can become in the near future the base of most important industries. Naphtha is found nearly everywhere in China, in Manchuria, in the Ussuri, in Japan, and in the island of Saghalien, which island also possesses a very rich coal basin, besides its very considerable lakes of naphtha.

An engineer who has examined the coal basins and the petroleum deposits of Texas and of Pennsylvania, and who has also made an exploration of the sources of the naphtha in the island of Saghalien, declared on his return to Bakou, that what he had seen in the United States was as nothing in comparison with what existed in that island. According to a report made by the consular agent of the United States at Vladivostok, the sources of naphtha near the river Nooteva in Saghalien, surpass in all respects the sources of petroleum in Bakou. There are subterranean lakes of naphtha in Saghalien, of which the largest alone has an area of about 72,000 square yards.

Note by Translator. The marvellous development of wealth, prosperity, knowledge and power that constitute the present civilization of the world, rests upon, and is measured by, the conversion of the heat ot mineral combustibles into physical work; and as fuel and power are convertible terms, and as the wonderful renaissance of Japan has shown that the Asiatics are in no respects inferior in imagination, intellect, ingenuity and personal prowess to Europeans and their descendents elsewhere, while their command of fuel and of population is vastly greater, the question arises whether in the not very distant future, that "star of empire which westward took its way" may not have reached its zenith and commenced its retrograde eastward march. The figure of Macauley's New Zealander standing on the ruins of London Bridge, may not prove to be altogether a figure of rhetoric. Never ceasing change is the law of the Universe.

New York, June 18, 1905. B. F. Isherwood.

Book Notices.

Die elektrochemische Industrie Deutschlands. Von P. Ferchland, Dr. Phil. Mit 4 Figuren und Tabellen im Text. 8vo, pp. viii×66. Hale a, S.: Verlag von Wilhelm-Knapp. 1904. Price, 2.50 maiks.)

This work constitutes Volume XII of the interesting and timely series of "Monographs on Applied Electrochemistry," which is being issued from the publisher's press. It gives a brief survey of the important electrochemical industries of Germany, where the development of this branch of applied science has been very great.

The work's author, after a brief historical introduction covering the origin and limitations of this branch of industry, and the sources of power production for electrochemical purposes, treats of the following special industries: Alkali and Chlorine (Bromine); Electrical Bleach; Hydrogen, Oxygen and Ozone; Calcium Carbide, Phosphorus; Sodium, Magnesium and Aluminum; Zinc; Copper, Nickel; Noble Metals; Other Inorganic Processes; Organic Electrochemistry; Power Consumption in the Production ot Electrochemical Materials. W.

Committee On Science and the Arts.

(Abstract of the proceedings of the stated meeting held Wednesday, June 7, 1905.)

Dr. Edward Goldsmith in the chair.

The following reports were adopted:

(No. 2216.) *The Nernst Lamp.* The Nernst Lamp Co., Pittsburgh, Pa.

Abstract: This report requires illustrations for proper understanding. It is accordingly reserved for publication in full.

The Committee's conclusions are as follows:

1st. The Nernst Lamp has come to stay and is filling an important place in electric lighting. It is economical in its use of energy; the color of the light which it supplies is attractive; it occupies a field midway between that occupied by the incandescent and the arc lamp.

2d. It is only applicable to A C circuits in which the voltage is quite steady. This limits its safe application to central station service in systems where the voltage is constantly under the supervision of experienced switchboard operators. The failure of the lamp under other conditions is not the fault of the lamp itself, but rather of the apparatus in every day use for distributing aternating current.

3d. Its commercial development in America in the hands of the Nernst Lamp Co. has made it possible to achieve the success in commercial operation which the lamp has met.

The report recommends the award of the John Scott Legacy Premium and Medal to the Nernst Lamp Co. for substantial improvements in the type of lamp devised by Dr. Walter Nernst. (*Sub-Committee*, Arthur J. Rowland, chairman; Thomas Spencer, Carl Hering, Geo. A. Hoadley.)

(No. 2313.) *The Semple Shell Torch.* John Bonner Semple, Pittsburgh, Pa.

Abstract: The object of this invention is to provide a means for the

rapid and accurate firing of projectiles at night, which has heretofore been a matter of extreme difficulty. This is practically overcome by the invention here considered. It is protected by letters-patent of the United States: Nos. 581,946, May 4, 1897, and 694,032, February 25, 1902, granted to applicant.

The distinctive feature of the shell torch is that it supplies the shell with a light which is ignited automatically a short distance beyond the gun and which burns during the entire flight of the shell, thereby rendering its trajectory clearly visible at night and vividly showing any error in the training of the gun. * * Another feature of the torch is that it will not be extinguished should it ricochet and pass under water.

The torch is attachable to any shell and consists of a brass cell filled with a pyrotechnic compound composed of ammonium nitrate, meal powder and magnesium powder, with just sufficient resin to hold the mixture together. The case is threaded to fit the opening of the shell intended for the base fuze or exploding device. The igniting apparatus is simple and is operated by a small quantity of gas from the propelling charge.

The great advantage of the shell-torch for night firing will be in siege operations, coast defense and the repelling of torpedo boats.

For further details, the reader is referred to the report, which will be published in full in the *Journal.*

The report proceeds to elaborate the various applications of the shell torch, and in conclusion makes the following recommendation, based upon the results of actual tests made by the military and naval authorities of the U. S. Government, viz: The John Scott Legacy Premium and Medal, to John Bonner Semple, of Pittsburgh, Pa., for his invention of a shell torch for firing projectiles at night. (*Sub-Committee,* Wm. O. Griggs, chairman; Frank Heath, Lt. Col. Ord. Dept. U. S. A., Comm'd't Frankford Arsenal; W. J. Williams, Chemist, Frankford Arsenal; Jos. H. Burroughs, late Major 1st Brig., N. G. Pa., Inspector of Rifle Practice.)

(No. 2338.) *Electrolytic Interrupter for Induction Coils.* Dr. A. Wehnelt, Charlottenburg, Germany.

Dr. Wehnelt's device is described as a contribution to science in the Elektrotechnische Zeitschrift, of January 26, 1889, to which reference is made for a suitable description. This report, also, will presently appear in full in the *Journal.*

The investigators conclude their report with the following recommendation: "In consideration of his work in the development of the electrolytic interrupter and its consequent adaptability to the practical application of the X-ray in surgical and other work, the award of the John Scott Legacy Premium and Medal is recommended." (*Sub-Committee,* Geo. A. Hoadley, chairman; Geo. F. Stradling, H. Clyde Snook.

(No. 2357.) *Photo-printing Machine.* L. F. Rondinella, Philadelphia.

The object of this invention is to product photographic prints in continuous form from tracings or other flexible transparencies of unusual length.

It is the subject of letters-patent of the U. S., No. 670,349, March 19, 1901, granted to the applicant.

The report will be published in full in the *Journal*.

The report finds that this inventor was the pioneer in this class of apparatus and concludes that "in view of the scientific accuracy and mechanical thoroughness and simplicity with which all the various requirements of the process of continuous photo-printing have been fulfilled in this machine," the inventor is entitled to the award of the John Scott Legacy Premium and Medal, the grant of which is accordingly recommended. (*Sub-Committee*, Louis E. Levy, chairman; Thos. P. Conard, H. R. Heyl.)

(No. 2360.) *Method of Producing Replicas of the Rowland Diffraction Gratings.* F. E. Ives, New York.

A full description of this method appears in the *Journal* for June, 1905, to which reference is made. The report in referring to the value of these replicas states that they show good definition and very little distortion, so that any part of the surface may be used with equal accuracy.

A photograph of the E b region of the solar spectrum made with one of these replicas in a Browning Student's Spectroscope shows with good definition every b group line that appears in the Angström and Kirchhoff maps, and more than fifty lines between E and b.

These replicas are low in price as compared with the cost of the original grating, and since they have the grating surface protected and are of a high grade of accuracy, they are well adapted for the use of students in the laboratory.

The investigators add that from tests made by their members, and with comparisons made with other forms of replicas, they are of the opinion that a valuable contribution has been made to apparatus for the study of light and its phenomena, and recommend the award of the John Scott Legacy Premium and Medal to the inventor. (*Sub-Committee*, George A. Hoadley, chairman; Louis E. Levy, George F. Stradling, Samuel Sartain.)

The following reports passed first reading:

(No. 2364.) *The Folmer & Schwing "Graflex" Camera.* Folmer & Schwing Mfg Co., Utica, N. Y.

(No. 2368.) *System of Flame Regulation.* Byron E. Eldred, New York.

(No. 2367.) *Drawing Pen.* Theodore Alteneder & Sons, Philadelphia.

(No. 2359.) *Alternating Current Motor.* Mitford C. Massie, Washington, D. C.

Wm. H. Wahl,
Secretary pro tem.

Sections.

Mechanical and Engineering Section.—*Stated Meeting* held Thursday, May 25th. Mr. James Christie in the chair. Present, sixty-four members and visitors.

The evening was devoted to a continuation of the discussion from the previous meeting (Thursday, April 27) on "Internal Combustion Engines." The Chairman opened the discussion with some general considerations on the subject.

Mr. J. R. Bivins, representing the Westinghouse Machine Co., Pittsburgh, followed with some interesting remarks on the theory of the inter-

nal combustion engine. Mr. Bivins's remarks were illustrated with the aid of a number of lantern pictures.

Mr. Henry Hess, representing the Hess-Bright Manufacturing Co., Philadelphia, followed with remarks having especial reference to the use of ball-bearings to reduce journal friction.

Mr. Francis Head gave a description of the Mietz-Weiss oil engine.

A general discussion followed, which was participated in by Messrs. John C. Parker, E. Goldsmith, Henry R. Heyl and the Chairman.

Adjourned. WM. H. WAHL,
Secretary pro tem.

Franklin Institute.

(Proceedings of the stated meeting, held Wednesday, June 21, 1905.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Wednesday, June 21, 1905.

PRESIDENT JOHN BIRKINBINE in the chair.

Present, twenty-six members and visitors.

Additions to membership since last report, eight.

The paper of the evening was presented by Mr. George W. Fuller, of New York. It was entitled "Sewage Disposal from the Standpoint of Oysters and Other Shellfish, Especially With Reference to their Transmission of Typhoid Fever." The speaker pointed out that laboratory tests both here and in foreign countries had demonstrated the presence of various disease germs in shellfish, their life in the oyster, clam, etc., ranging from seven to twenty-one days, and said that while notable epidemics due to the eating of sewage-contaminated oysters are comparatively rare, there is no room for doubt that numerous sporadic cases have resulted from this cause. The investigations by the Royal Commission on Sewage Disposal of England, he said, indicate that about 10 per cent. of the total deaths from typhoid in London and Manchester are due to eating infected shellfish, but data on this point, in this country, have not been studied with sufficient care to give accurate conclusions.

The paper was discussed by Dr. George A. Loper, of New York: Dr. Henry Leffmann, of this city, and Kenneth Allen, engineer of the Water Supply of Atlantic City, all of whom agreed with the author of the paper that there should be a competent sanitary inspection of oyster beds in their relation to sewage contamination and that the sale or shipment of contaminated oysters should be prohibited by law.

The President expressed the thanks of the meeting to the speaker of the evening and to the participants in the discussion, and the meeting was adjourned.

WM. H. WAHL,
Secretary.

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THE FRANKLIN INSTITUTE

(Stated Meeting, held Wednesday, June 21, 1905.)

Concerning Sewage Disposal from the Standpoint of Pollution of Oysters and Other Shellfish, and Especially with Reference to their Transmission of Typhoid Fever.

BY GEORGE W. FULLER, Member of the Institute.

[This paper contains a concise summary of the most prominent instances of epidemics of typhoid fever and other diseases due to polluted oysters and other shellfish. The literature is reviewed, with numerous references as to the behavior of the germs of typhoid fever in fresh water, salt water and in the shellfish themselves. The extent of the oyster industry and its distribution along the Atlantic seacoast are indicated, together with the mode of growth of shellfish and the relation of their life history to polluted waters, which in some instances surround oyster beds and drinking grounds. Enteric diseases due to polluted shellfish occur with sufficient frequency to call for an improved regulation of this industry, to the mutual benefit of the oyster men and of the public. Suggestions as to means of accomplishment are made, with references to efforts in this direction abroad—THE EDITOR.

Until quite recently, in considering the disposal of sewage from cities on the sea coast or on tidal estuaries, not much at-

tention has been given except in a general way to the pollution of shellfish.

At present, however, there are some instances where this question is of such importance that it may have much bearing upon the decision as to the best method of sewage disposal to meet the requirements of the near future. To investigate this matter properly there is required a wide range of information in the premises, much of which is not now thoroughly crystallized. Indeed, in a number of ways the evidence is complicated and perplexing, as is indicated by the fact that after several years of investigation the Massachusetts State Board of Health has not formally reported upon the subject; and also that the Royal Commission on Sewage Disposal in Great Britain in its elaborate reports of last year left many important details still undecided.

Academically this question is not new. It is ninety years since the available records first show reasonably authentic cases of typhoid fever having been caused by the eating of infected oysters. It is more than ten years since the epidemic of typhoid fever at the Wesleyan University, at Middletown, Conn., was shown so clearly by the classical investigations of Prof. Conn to have been due to infected oysters. From various places evidence is forthcoming as to disease having resulted in sporadic cases from the eating of oysters which were polluted with sewage.

The "oyster scare" is founded upon fact to a sufficient degree to deserve serious attention, and that it has not been more completely and satisfactorily investigated indicates, in the opinion of the writer, the absence of a keen appreciation of the sanitary welfare of the public and also of the interests of the oyster industry.

The purpose of this paper is not to bring forth any new data, but rather to summarize briefly the more authentic information in the premises now available from various sources, and to point out some lines along which further data are needed before this subject may reach a sound and logical conclusion, having due regards to the interests of all concerned.

Epidemiology, bacteriology, sanitary chemistry and hydraulic engineering are called to assist in the solution of this problem, in conjunction with those physical data usually called a

"sanitary survey." The breadth of this subject is indicated by the following list of topics here considered. To consider one aspect of the case will not do, as such evidence might be misleading to such a degree as to do far more harm than good. In the future the engineer will especially be obliged to consider this question in further detail, and to co-operate in seeing to it that various sanitary surveys and samples for analysis have due regard for the physical side of the case, as, for example, the currents, tides, winds, relative volumes of sewage and of fresh and salt water (tidal prisms), velocity, dilution, effect of sedimentation and scouring, temperature, relative densities of water, stratification, and especially the period of time elapsing during the passage of sewage from the outfalls to the shellfish beds and "drinking grounds."

Early Instances of and References to Disease Transmission through Infected Oysters.

Recent Outbreaks of Typhoid Fever due to Infected Oysters and other Shellfish.

Relation of Shellfish to the General Prevalence of Typhoid Fever.

Extent of the Oyster and Clam Industry.

Concerning the Life History of the Oyster.

Concerning the Detection of Typhoid Fever Germs in Oysters and in Water.

Life of Typhoid Fever Germs in Sea Water.

Bacterial Contents of Unpolluted Sea Water.

Bacterial Contents of Oysters and other Shellfish taken from Unpolluted Waters.

Life of Typhoid Fever Germs in Live Oysters in Sea Water.

Life of Typhoid Fever Germs in Dead Oysters.

Resistance of Typhoid Germs to Heat.

Relative Vitability of B.coli and B.typhosus in Water.

Sanitary Condition as shown by Inspection of Beds and Fattening Grounds of Oysters and other Shellfish.

Bacteriology of Commercial Shellfish and Associated Waters.

Pollution on the Outside of Oysters.

Re-laying of Oysters.

Summary.

EARLY INSTANCES OF AND REFERENCES TO DISEASE TRANSMISSION THROUGH INFECTED OYSTERS.

Even prior to the germ theory of disease numerous cases were cited of the well established relationship between typhoid fever, cholera and similar intestinal diseases and the eating of oysters and other shellfish taken from polluted sources.

The first instance on record was cited by Dr. Pasquier[1]* in 1816. This French physician wrote a book entitled "The Oyster from the Medical Point of View," and in it described an instance where a workman laid down 60,000 oysters in a fattening bed excavated in the moat of an old citadel into which the sewage of the garrison had been discharged for centuries. These oysters were consumed for the first time on September 10, 1816, and on the 20th and 21st of the same month, after the lapse of the necessary period of incubation for typhoid fever germs, cases of that disease made their appearance among the consumers.

In 1820 the British medical journals[2] record an outbreak of gastro-enteritis at Dunkirk which was reported to have been due to oysters procured on the coast of Normandy.

During the cholera epidemic in Great Britain in 1849 an outbreak of this disease occurred at Bridgewater and Taunton, which was considered to have been due to the consumption of some apparently decomposing oysters which had been condemned as unfit for food, but which were, nevertheless, given to school children in the district. This outbreak was officially examined by Dr. Britton, of the General Board of Health, and was referred to a little later in medical literature by Sir D. W. Richardson[3].

In 1876, on the Isle of Man there occurred an epidemic of typhoid fever[4] which was alleged to have been due to the consumption of oysters.

The earliest reference in recent medical literature to this subject occurs in a paper read before the British Medical Association, in 1880, by Sir Charles Cameron[5], Health Officer of Dublin, Ireland. His proposition that oysters obtained from polluted sources might cause typhoid fever was so novel that the chairman of the meeting inquired if his paper were intended as a joke. In 1889, it appears from the investigations of this gentleman that cases of typhoid fever in Dublin[6] were recorded as possibly having had their origin from oysters which had been laid down in the sewage-polluted Dublin Bay.

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*The numbers appearing throughout this paper refer to the list of references which has been consulted, and which appears at the close of the paper. Acknowledgment is here made for the use of information quoted from the several authors and reports as indicated.

Prof. de Giaxa, of Pisa, made a study of the bacterial flora of the Bay of Naples and in his paper[7] in 1889 recorded some observations on the longevity of disease germs in salt water, and referred then and later[7a] to the question of infection by shellfish.

Following the epidemic of cholera in Hamburg late in 1892 there appeared some scattering cases of cholera in England which were considered to have been directly caused in part by the consumption of oysters from Cleethorpes and Grimsby, according to Sir R. Thorne Thorne[8], Medical Health Officer of the Local Government Board, and Dr. Reece, Inspector.

RECENT OUTBREAKS OF TYPHOID FEVER DUE TO INFECTED OYSTERS AND OTHER SHELLFISH.

The epidemic of typhoid fever which has attracted most widespread attention was that at Wesleyan University, at Middletown, Conn. As stated in the admirable report of Prof. Conn[9], there were seven fraternity banquets on October 12th, 1894, at Middletown, which were attended by about 100 students, some of whom were guests from other universities. Following the ordinary period of incubation of typhoid fever, 23 cases of this disease appeared among the local students and six cases among the guests who had attended three of these banquets. By a most exhaustive inquiry there were eliminated other foods which might possibly have conveyed the typhoid fever germs, including water, ice, milk, ice cream, uncooked vegetables, etc. By eliminating these articles of food and drink and by comparing the portions of the menu eaten by those who did and by those who did not sicken of typhoid fever, and further by comparing the diet before and after the banquet of the various students and guests, there was left no room for doubt about the uncooked oysters being the source of infection. Additional weight was given to this conclusion by the appearance of typhoid fever among six of the guests who had eaten oysters at these banquets but who had not otherwise been exposed to any local factors; and by the further fact that no typhoid fever appeared among students attending on the same evening the other banquets at which oysters were served either from other sources or were cooked.

Investigation showed that the oysters in question had been obtained from Fairhaven, Conn. They had been taken from deeper water in Long Island Sound and brought into the mouth of a creek known as Quinnipiac River and allowed to lie in brackish water for a day or two for fattening. Close to the fattening beds were the outlets of a number of private sewers, one of which, 300 feet distant from the bed, drained a house in which were two cases of typhoid fever. Each link in the chain of evidence was established beyond all reasonable doubt.

It was the Middletown epidemic which first drew the attention of the public in a prominent way to the relation between shellfish and disease. Since that time many instances have occurred of somewhat similar character.

Among those which were investigated most carefully by competent official sanitarians may be mentioned the mayoralty banquets[10] in 1902 at Winchester and Southampton, England. In this instance there were two banquets, held on the same evening in distant towns, at which oysters from the same polluted source were served uncooked. At each banquet a considerable portion of the guests were shortly siezed with gastro-enteritis, and others were later attacked with typhoid fever. Of 267 guests, 118 suffered from the former and 21 from the latter disease.

Instances of such outbreaks are a matter of record in nearly all countries where oysters or other shellfish are eaten in an uncooked condition. It is needless here to recite them all in detail, the particulars of which can be largely ascertained in Dr. Bulstrode's testimony[4] and his classical paper[11] on "Oysters Culture in Relation to Disease," and in the excellent summary prepared in 1901 by Dr. Harrington[12]. As a matter of convenient record, however, reference may be made here to a few of the more prominent ones, as follows:—

Truro, England.—A supper party of seven in this city was reported to have eaten oysters from a source known to be polluted. All of them were taken ill, some with typhoid fever and some with gastro-enteritis. The Medical Officer of Health of the city, Dr. Sharp[13], reported in 1897 that the infected oysters were the cause.

St. Andre de Sangonis, France.—Dr. Chantemesse[14] read a

paper on this subject before the Paris Academy of Medicine. He drew attention to 14 persons in 6 families having eaten raw oysters taken from the sewage polluted canal at Cette. All of these persons were made ill, some with typhoid fever and some with gastro-enteritis, while no illness whatever appeared among the members of these families who ate no oysters.

Dr. Mosny[15], who wrote an excellent series of articles five years ago on "Mollusk Poisoning" in France, refers to a more recent instance in a village near Paris, where gastro-enteritis followed the eating of oysters from Cette.

Other instances of oyster pollution are reported from Monte Carlo[16], Naples[16], Florence[17], Milan[18], Constantinople[19] and New Zealand[20]. Numerous physicians could doubtless recite cases of shellfish infection within their observation, typical instances of which were recorded by Sir William Broadbent in 1895[21].

Clams[22], mussels[23] and other shellfish have been found to transmit disease, but as they are not so generally in use as oysters (at least in America), the well-known cases are not so numerous as with the oysters.

Patrons of summer resorts, especially at the seashore, doubtless suffer more from infected shellfish as a general proposition than is believed by many. To trace clearly the significance of such factors in a floating population is obviously difficult. It is of interest, however, to mention the recent instances at Atlantic City and at Lawrence, L. I.

Atlantic City, N. J.—This well-known seashore[24] resort, although provided with a public water supply of satisfactory quality, and with a milk supply found upon careful examination to have been safe, has at times suffered from an undue prevalence of typhoid fever, especially during the summer of 1902. The cause of this typhoid fever was found to be largely due to oysters freshened in sewage-polluted waters, and clams taken from similar waters, according to an investigation[24] made by the Atlantic City Academy of Medicine. This conclusion[25] was concurred in by Prof. A. C. Abbott and Prof. Henry Leffman, of Philadelphia. Since the taking of shellfish from polluted sources has been prohibited by the local Board of Health

there has been no abnormal prevalence of typhoid fever[26] at this resort.

Lawrence, L. I.—This small summer resort on the Rockaway peninsula, on the south shore of Long Island, suffered during the summer and autumn of 1904 from a sporadic outbreak of typhoid fever, the total number of cases being thirty-one. According to the careful investigation of Dr. Soper[27] more than two thirds of these cases were traced directly or indirectly to shellfish taken from the adjoining coves of Jamaica Bay, the water of which is polluted with local sewage.

RELATION OF SHELLFISH TO THE GENERAL PREVALENCE OF TYPHOID FEVER.

A moment's reflection will show that the most serious aspect of oyster pollution does not relate by any means to outbreaks at large banquets or summer hotels, but rather to the significance which this proposition bears to the various cases of this disease scattered throughout the entire world of oyster-eating people. It is well known that typhoid fever frequently appears among people who, so far as can be ascertained, have not been exposed to infected water, milk or other foods, and which constitute what are generally called sporadic or isolated cases of typhoid fever.

To ascertain even in a general way the relation of various shellfish to these isolated cases is a very difficult and complicated matter. In the recent inquiry conducted in a most careful manner into this general proposition by the Royal Commission[28] of Great Britain on the Disposal of Sewage, a circular letter requesting information upon this subject to thirty-one county councils, drew forth the fact that twenty-one of them had no evidence bearing upon the question. The principal information elicited by these letters from the remainder may be briefly summarized as follows:

Southend-on-Sea, England.—The Health Officer, Dr. Nash[29], expressed his opinion, as the result of careful investigation, that at least 50% of the typhoid fever was due to the consumption of shellfish from sources contaminated by sewage.

Yarmouth, England.—Dr. Nash also quoted typhoid fever statistics from Yarmouth[29], where this disease had prevailed to a high degree for several years prior to 1900, when the sale

of mussels from the River Yare was stopped. In 1901 the typhoid fever records showed only about 30% of the previous average, and in 1902 there was a still further reduction.

Brighton, England.—During the years 1894 to 1902, the Health Officer, Dr. Newsholme[30], investigated each case of typhoid fever in Brighton and found that out of a total of 643 cases 158 were directly ascribable to the consumption of oysters and eighty other cases to the consumption of other shellfish within the period of incubation. These shellfish in each instance were taken from layings proven to be exposed to sewage pollution. In the opinion of Dr. Newsholme 37% of all cases as indicated above is an under estimate of the effect upon that community of polluted shellfish.

Manchester, England.—During the years 1897 to 1902, inclusive, 2664 cases of typhoid fever occurred, and according to the Health Officer, Dr. Nevin[31], 118 of these were strictly ascribable to oysters and mussels, and 156 more were associated with the consumption of other shellfish. In round numbers, therefore, in the city of Manchester about 10% of the typhoid fever during this period seems to have been due to polluted shellfish.

London, England.—According to Health Officer Murphy[32], of the Metropolitan District of London, more than 8% of all the typhoid fever in that district during 1902 was indicated by consistent evidence to have been caused by polluted shellfish.

In America the evidence obtained as to the relation between typhoid fever and shellfish has not been exhaustively studied, although it has received considerable attention in New York City[33] and in some other places. There are no adequate data on which to base any comparisons with the experiences in the English cities above cited. When the much-needed data upon this question are available it will probably be found that the wider use of shellfish in America than in Europe will be a factor; although, of course, the net result depends upon the number of infected oysters reaching a given population.

EXTENT OF THE OYSTER AND CLAM INDUSTRY.

The principal oyster in America, *Ostrea Virginiana,* is found along the Atlantic coast, from Cape Cod to Texas. The extent of this industry and an approximate idea as to its relative

distribution along the coast is shown in Table No. 1. These annual statistics are compiled from the bulletins[34] of the U. S. Bureau of Fisheries, Department of Labor and Commerce. They cover the year 1902, except in the case of the Middle Atlantic States, where the records are for the year 1901.

TABLE No. 1.

	Market Oysters		Seed Oysters		
	Bushels	Value	Bushels	Value	Total Value
Massachusetts	75,586	$ 120,252	27,800	$ 13,430	$ 133,682
Rhode Island	516,479	561,291	91,550	26,761	588,052
Connecticut	848,065	872,634	1,233,469	598,948	1,471,582
New York	1,768,703	1,703,985	544,075	267,555	1,971,540
New Jersey	2,092,335	1,696,767	1,516,796	550,918	2,247,685
Pennsylvania	40,336	35,517	43,234	14,232	49,749
Delaware	96,900	40,290	76,290	22,318	62,608
Maryland	5,685,561	3,031,518	....	......	3,031,518
Virginia	6,067,669	2,621,915	1,817,778	301,541	2,923,456
North Carolina	1,022,813	268,363	....	......	268,363
South Carolina	689,700	118,460	....	......	118,460
Georgia	1,224,000	220,467	....	......	220,467
Florida	888,556	161,296	....	......	161,296
Alabama	347,460	119,773	....	......	119,773
Mississippi	2,405,132	426,222	....	......	426,222
Louisiana	1,198,413	493,227	....	......	493,227
Texas	343,113	100,359	....	......	100,359
Totals	25,410,821	$12,592,336	5,350,992	$1,795,703	$14,388,039

In Table No. 2 are given corresponding annual statistics showing the extent and location of the clam industry. The so-called "Little Neck" clam, or small round clam, in most general use is here classified as the hard clam, or what is commonly known in New England as the "quahog."

TABLE No. 2.

	Hard Clams		Soft Clams		
	Bushels	Value	Bushels	Value	Total Value
Maine	....	....	417,496	$148,742	$ 148,742
New Hampshire	....	....	3,000	3,000	3,000
Massachusetts	106,818	131,139	227,941	157,247	288,386
Rhode Island	27,155	35,456	26,490	32,514	67,970
Connecticut	18,927	24,762	22,460	26,743	51,505
New York	184,736	257,756	77,945	58,843	316,599
New Jersey	530,759	552,953	90,277	54,918	607,871
Delaware	1,025	1,203	......	......	1,203
Maryland	13,450	14,384	......	......	14,384
Virginia	220,585	134,777	......	......	134,777
North Carolina	146,897	86,662	......	......	86,662
South Carolina	28,133	12,940	......	......	12,940
Georgia	1,250	825	......	......	825
Florida	750	425	......	......	425
Totals	1,280,485	$1,253,282	865,609	482,007	$1,735,289

On the Pacific coast there are two local varieties of oysters

found, available records indicating that the annual output amounted to 519,340 bushels, having a first value of $971,829.

A general idea of the extent of the oyster industry throughout the world is shown in Table No. 3, the annual statistics[35] of which it is to be stated are not strictly comparable, as they refer in various instances to different years, beginning about 1890 and extending down to the present time. They are sufficient, however, for present purposes in conveying a general impression as to the relative extent of this important industry.

TABLE No. 3.

	Oysters.	
	Bushels.	Value.
United States	28,138,434	$14,313,753
Great Britain	2,760,000	6,200,000
France	2,000,000	5,000,000
Canada	152,580	183,846
Holland	70,000	444,000
Italy	65,000	200,000
Germany	13,000	75,000
Other countries	400,000	600,000
Totals	33,599,014	$27,016,599

The value of the annual output[36] of oysters, clams and other mollusks amounts in the United States to about one-third of the total volue of all fisheries, as shown in Table No. 4.

TABLE No. 4.

Oysters and other molusks	$16,700,524
Lobsters and other crustaceans	2,251,869
Whales, seals and other animals	1,321,247
Menhaden (for oil and guana)	973,200
Sponges	305,589
Turtles, terrapin, alligators, frogs	254,922
Food fishes in general	27,889,588
Total	$49,696,939

CONCERNING THE LIFE HISTORY OF THE OYSTER.

It is not the intention of this paper to enter into a detailed technical description of the anatomy or physiology of the oyster. It is desired, however, to refer somewhat briefly to those well-known features of its mode of living which bear a relation to possible opportunities for the oyster to become polluted when placed in water containing sewage or other undesirable drainage.

Larval Oysters.—Like all other mollusks, the oyster reproduces exclusively by eggs. Each spatting oyster is estimated

to give rise to more than 1,000,000 ova in a single season. From the eggs there are hatched small free-swimming larvae, which swim about for a short time until the shell appears. They drift about with the tide, current or wind and are carried frequently far away from their native bed. A large proportion of them, however, never reach maturity. Not only are the larvæ destroyed by cold and by living enemies in the water, but many of them perish by becoming deposited in muddy places, where survival is impossible. After the larvae pass through the free-swimming stage for a few days, those which develop further become fixed upon some hard, clean substance.

Oyster Spats.—When the shell of the infant oyster becomes large enough to cause deposition it is commonly called at this stage of development the "oyster spat." It has the appearance of a white glistening speck, not unlike a spot of candle grease. The spatting season varies in different localities, but ordinarily occurs within the period from May to September, inclusive. The oyster farmer gives careful attention to the "fall of spat," and in many instances artificial collectors are provided upon which they may become deposited. These frequently consist of clean empty oyster shells, branches of trees, tiles, etc. In the natural beds the spats become attached to rocks or reefs; if they do not reach some solid support they obviously sink in the mud and become smothered. Care is required to keep the beds in good condition as to freedom from weeds, deposits and antagonistic kinds of life.

Seed Oysters.—The seed oyster is one which has grown sufficiently upon artificial collectors until it has reached perhaps one year of age or so, when it is frequently removed to other beds. It is said that about 40% of the oysters in the United States are obtained from natural beds, and the remainder are transplanted to places where the oyster does not breed or grow to advantage. Probably the most important factor of all is the fact that the natural beds cannot supply the demand. For some time oyster transplanting has become an industry carried out on a large scale in this country, and is now receiving much attention. The future will doubtless see still further attention to oyster culture.

Food Supply.—The oyster lives on the various suspended matters contained in sea water, about 90% of the food being

diatoms, or low forms of plant life which are capable of growing on the mineral contents of sea water. This suspended matter reaches the stomach of the oyster after having been filtered out from the water which passes through the gills. This process[37] is well described by Prof. Brooks, of Johns Hopkins University, as follows:

"Every oyster in the bay is engaged day after day throughout the year, all day and nearly all night, in drawing into its shell a stream of water, filtering this through its gills, and then discharging this stream of water again. This stream can be traced for five or six feet away from the oyster by the disturbance it produces in the water. In fact, I think it is hardly an exaggeration to say that every drop of water that enters the Chesapeake Bay from the Susquehanna River has a good chance to be filtered through the gills of an oyster before it reaches the ocean. After the oyster draws this stream of water into its shell, the water passes through microscopic pores over the surface of the gills, and out again through the vent pipe. During this process all microscopic organic life, or most of it, is filtered out. This is so true that those who manage aquaria have long been aware that water that has been filtered by the fresh water mussel is peculiarly adapted to their use, because it does not contain the germ of the green algae, which grow so profusely upon the sides of glass vessels, this material being so perfectly taken out by the mussel that the glass remains clean for a long time. The oyster does the same thing. These organisms, instead of going through the pores of the gills with the water, are entangled in the cement which the gland cells of the gills are continuously pouring out, and they are pushed along until they reach the mouth of the oyster, and are passed along into the stomach, where they are ultimately digested and converted into the wholesome substance of the oyster."

Fattening of Oysters.—In all countries one of the characteristic features of the oyster industry is the frequent, though not universal, custom of removing the oysters with rakes or dredges, after they have grown to be a sufficient size, from the oyster beds proper and their placement for a day or two in drinking houses, or floats. The latter are located ordinarily in coves or bays, or in the mouths of fresh water streams where the water

is brackish. The object of this is to "fatten" the oyster, which really means to bloat, bleach and freshen it. This is accomplished by the oyster drinking a comparatively large quantity of the brackish or fresh water, thereby, on account of difference in the specific gravity, causing it to become bloated, with the salty flavor due to sea water largely removed, and also giving it a much lighter color, due to its being filled with fresh water.

This bloating process—which the oystermen say increases the market value of the product, but which is seriously objected to by devotees of fine oysters—is not to be confused with fattening, which in a limited way is done by transplanting to shallow bodies of salt water where the diatomaceous food is more abundant[38] than around the natural beds. The latter process is an important branch of artificial oyster culture which has long received attention in France and elsewhere.

Enough has been said above to make it plain that the oyster, even in natural beds, may at times be found in a water which is dangerously polluted with sewage, and that particularly dangerous pollution may be afforded by the custom of bloating the oysters by removing them just prior to their being marketed to special layings along shore. It is also apparent from what is said above that if disease germs are contained in the water in which the oysters are placed, there is a strong likelihood of these germs being filtered out by the oyster as the water passes through its gills, and entering the body of the oyster.

We will now trace the available evidence as to the significance of disease germs entering the oyster body.

CONCERNING THE DETECTION OF TYPHOID FEVER GERMS IN OYSTERS AND WATER.

In the present state of the art, bacteriology does not afford ready and reliable means[39] for the detection and isolation of the bacillus of typhoid fever when present in such numbers as ordinarily exist in nature. With difficulty the numbers present may be roughly approximated only in the laboratory when those present are excessively numerous due to artificial infection of the oyster or the water.

Accordingly, in the absence of direct means of studying the distribution of this germ in oysters and associated waters, it becomes necessary to study the problem indirectly. Along the

latter line there are five principal ways of approaching the subject, viz.:

(a) Evidence as to the longevity of the typhoid germ in sea water. This evidence is, of course, considered in connection with the time interval required for the passage of sewage from the local outfalls to oyster beds in the vicinity.

(b) Topographical and physical evidence, such as distances, depths, volumes, tides, currents, etc., for studying each local problem as indicated in the foregoing paragraph.

(c) Comparison of the numbers of bacteria and organic contents of the water from above the oyster beds with that of sea water from unpolluted sources, paying special attention to the relative numbers of B. coli, which is the most prevalent species of bacteria in the intestines of man and other warm-blooded animals.

(d) Comparison of the B. coli contents of oysters (including the body, liquid and shells) from unpolluted sources with those from the locality in question.

(e) Evidence, so far as present methods of bacteriology permit, as to the behavior and duration of life of typhoid fever germs within and upon oysters which have been infected with this germ.

LIFE OF TYPHOID FEVER GERMS IN SEA WATER.

Available evidence, summarized in Table No. 5, indicates that this germ will live in unsterilized sea water in gradually decreasing numbers for periods ranging at least from about one week to one month, depending upon local conditions.

TABLE No. 5.

Observer	Date.	Days after Infection when Germ was last Observed.
De Gaixa[7]	1889	9
Foote[40]	1895	17
Klein[41]	1896	21
Burdoni-Uffredizzi[18] and Zenobi	1889(?)	14
Herdman & Boyce[42]	1899	20
Field[43]	1904	10

No observer has noted any signs of the typhoid germ multiplying in sea water.

According to Klein[41], germs of Asiatic cholera behave in a

similar manner in sea water to typhoid germs, except that their continuance of life is apparently somewhat shorter.

Experiments have been made both by Klein[41] and Field[43] in which there was a gradual displacement of the infected sea water by uninfected sea water. The apparent result was a shortening of the life of the typhoid germ, but it is not clear how far this was a matter of elimination from the vessel by displacement of the water containing them.

In all other tests included in the above tabulation the infected sea water remained undiluted.

Generally speaking, it is seen that the life of the typhoid fever germ in salt water is very similar to that in fresh water, according to a diagram prepared by Whipple[44] and embodying all of the best available data. Careful experiments recently made jointly by Jordan, Russell and Zeit[45] indicate, however, that hostile influences within the local Chicago drainage canal water (fresh and sewage polluted) may cause the vast majority of typhoid germs to perish within three or four days. They specifically mention that these data are not intended to be representative of all conditions in all bodies of water. In this regard attention is directed to the fact that, due to the limits in accuracy of present laboratory methods, some disease germs without any question remain in the water for a longer period than indicated by the data here given. This obviously follows when consideration is given both to the difficulty in detecting typhoid fever germs when sparsely distributed in water and to the fact that the examination in question involved the testing of a far smaller volume of water than is daily drunk by an oyster. In short, 90% of the typhoid germs disappear from infected water according to different local conditions in from 3 to 13 days, according to Whipple's[44] diagram; and while the remainder, without doubt, gradually perish, there is no way at present of stating the period of survival of the last 1% or 0.1%.

The use of parchment sacs is supposed to have improved the technique of determining the longevity of typhoid germs in water; but very recently doubt upon this point has been thrown by the observations of Messrs. Johnson and Copeland, indicating that motile bacteria may pass through unpunctured sacs. It is hoped that further data on this subject will be forthcoming in the reports from the Columbus Sewage Testing Station.

BACTERIAL CONTENTS OF UNPOLLUTED SEA WATER.

Numbers of Bacteria.—Far distant from the land the water of the ocean, while by no means sterile, contains comparatively few bacteria, and all of these appear to be of a harmless kind. Thus, Levin[46] found during an expedition to the Arctic regions that the water in that locality according to the average of numerous analyses contained 11 bacteria per c.c. This number he compares with 700 per c.c. as the contents of sea water off the shores of Sweden.

In midocean, on a voyage across the Atlantic, Minervini[47] found that the number of bacteria ranged from 8 to 140 per c.c, and averaged about 60 per c.c. That these samples were not sterile is not so surprising as might appear at first sight, as the flora and fauna of ocean waters naturally furnish food for bacterial life. Thus Minervini[47] records that in midocean several tests of the organic matter in sea water showed about 25 parts per million of oxygen consumed, according to the Kubel method.

These numbers found in the middle of the Atlantic Ocean correspond quite closely with those found about two and one-half miles or more distant from the coast by Russell[48] in the Gulf of Naples and by Carta[49] in the Gulf of Genoa.

The sediment on the bottom of the ocean was studied by Russell[48] and found to bear quite a close relation to the relative numbers in the water above when the distance from shore exceeded that covered by the zone showing immediate effect of shore pollution. Within this zone, showing gradually decreasing effect of pollution, numerous bacteria were naturally found in the sediment.

Fisher[50] also made numerous examinations of sea water on a prolonged ocean voyage to the Antilles, and found the bacterial contents to be generally similar to the above.

Tests for B. coli.—B. Coli is the principal species and by far the most abundant one in the intestines of man[51] and other warm-blooded animals[52]. Waters in which this germ is regularly absent in from 1 to 10 c.c., are found to be quite unpolluted, while the pollution ofwaters is now quite generally measured by the comparative numbers of B. coli present, according

to methods recently formulated both in America[39] and Great Britain[53].

The evidence is decisive that unpolluted sea water, remote from sources of pollution, contains no B. coli. The most complete tests available were made for the Royal Commission on Sewage Disposal by Dr. Houston[54]. Of thirty-five samples of sea water collected off the coast of Scotland within sight of land but distant from any appreciable local pollution, thirty-four were found to contain no B. coli even when 100 c.c. portions were examined. The remaining sample gave a positive test with 10 c.c.

This evidence is in accordance with the result of studies as to the distribution of numbers of bacteria and of B. coli which have been made in this country of the waters of the Great Lakes some distance from land, especially in the vicinity of Toronto[55], Chicago[56], Milwaukee[57], Oswego[58], Buffalo[59], and Cleveland[60].

Influence of Fish.—The question of fish comes up for consideration with reference to B. coli being found in sea water at points considerably removed from sewage pollution. The evidence upon this point is not as complete as desired, but the observations of Amyot[61] and Whipple[62] indicate that B. coli is not a normal inhabitant of the intestines of fish. The studies of Russell and Bassett[63] leave the matter in doubt, but Johnson[64] found that where fish live for some time in polluted waters the intestines of the fish contain this germ. On the whole it is quite apparent that in unpolluted sea water B. coli coming from fish does not interfere seriously with the proposition that B. Coli is absent from such water.

Influence of Birds.—While the fecal discharges of birds[52] contain B. coli, the influence of this factor is apparently negligible as a general proposition upon the normal contents of deep sea water. Exceptions could appear only in chance samples, which are always to be avoided as they are apt to lead to errors.

Influence of Boats.—Refuse matter discharged from boats in the opinion of some is entitled to some weight as a factor influincing the quality of deep sea water. At intervals this is probably true for small volumes, but the effect of such would be hardly appreciable in a comprehensive set of examinations.

Generally speaking, we may say that deep sea water distant from local sewers is unpolluted according to B. coli tests.

BACTERIAL CONTENTS OF OYSTERS AND OTHER SHELLFISH TAKEN FROM UNPOLLUTED WATERS.

The most exhaustive investigations upon this subject show that normally the oyster and other shellfish contain not only no specific disease germs, such as that of typhoid fever, cholera, etc., but, further, that the oyster contains no Bacillus coli, which, as already stated, is the prevailing organism in the intestines of man and other warm-blooded animals.

Dr. C. A. Fuller[65], formerly of Brown University, Providence, R. I., examined most carefully various portions of each of 200 oysters taken from unpolluted sources, as well as the liquid contained in the shell. In no instance did he find any bacteria which could be classed with the B. coli group.

Clark and Gage[66], who have investigated this matter extensively for the Massachusetts State Board of Health, concur in this conclusion that B. coli is not a normal inhabitant of either clams or oysters.

Investigations leading to the same general inference have been made in various laboratories abroad, among which may be mentioned those of Klein[67], Houston[68], and Hewlett[69].

In regard to numbers of bacteria contained in the alimentary canal of oysters, Herdman and Boyce[42] found from 0 to 5 in deep-sea oysters when testing on agar. Oysters from shops contained from 1 to 1200 on agar, and from 1700 to over 20,000 on sea-water gelatine.

LIFE OF TYPHOID FEVER GERMS IN LIVE OYSTERS IN SEA WATER.

Evidence upon this proposition has been obtained by several observers by putting oysters from unpolluted sources into small receptacles containing sea water infected with typhoid fever germs. From time to time examinations were made of the tissues, pallial cavity, alimentary tract, shell water, etc., of the oysters. All observers have found that these disease germs penetrate the oyster body and live there in gradually decreasing numbers for various periods ranging from about one week to one month. In no case has anyone observed any signs of multiplication of typhoid germs within a live healthy oyster.

The principal data upon this point are summarized in Table No. 6.

TABLE No. 6.

Investigator.	Date.	Period. Days.	Remarks.
Foote[40]	1895	30	Lived longer in oyster than in water.
Chantemesse[42]	1896	2	
Klein[41]	1896	17	No record of period of elimination.
Herdman&Boyce[42]	1899	14	Lived longer in water than in oyster.
Field[42]	1904	9	

In each case there is doubt about all of the typhoid germs having died within the period given; the records simply show the period up to the time when it was last observed.

Attention is called to the fact as noted in the table, under "Remarks," that the comparative longevity of the germ in the oyster and in the surrounding water differed with the different observers. Generally speaking, the life within the oyster was found to be very similar to that in sea water as shown in Table No. 5, and the remarks made in that connection are also applicable here.

Herdman and Boyce[42] made tests to ascertain how long a period was required in which to remove typhoid germs from infected oysters by subjecting them to a running stream of pure sea water. In seven days they found practically a total disappearance.

Field[43] found upon changing each day the infected oysters to a new clean tank of uninfected sea water that the specific germ within the oyster (and also clams) could not be found after four days.

In each of the latter tests it is to be noted that the period was about one-half of that observed where the oysters remained in the originally infected water.

As large numbers of typhoid germs were used in infecting the oysters in these tests, under conditions less favorable from a sanitary standpoint than ordinarily occurs in nature, these data show in this regard abnormally long periods of life. How far this aspect of the case goes to offset limitations in laboratory methods for the detection of the specific germ is a question which cannot now be decided.

LIFE OF TYPHOID FEVER GERMS IN DEAD OYSTERS.

Field[43] notes the result of some experiments in which he observed a well defined growth of typhoid fever germs in some

dead and dying oysters in sea water. These oysters were infected with enormous numbers of typhoid germs, and the conditions of the test would in this regard be rarely, if ever, duplicated in nature. The great mischief which could be done by one dead infected oyster among a lot of oysters suggests at once that this matter should be investigated most thoroughly.

This possibility of growth of typhoid germs on dead shellfish is accepted by Dr. Nevin[31] and mentioned in his testimony before the Royal Commission, but the evidence to support it seems to us to be very limited.

Klein[70] makes no mention of this question, but he records some observations indicating that the typhoid germ may multiply in cockles.

The question of growth of typhoid germs on cooked oysters, in instances where some, but not all, of a lot of infected oysters are killed by cooking in the same receptacle, is a matter worthy of serious consideration.

The antagonism[71] of other kinds of bacteria towards the typhoid germ is a very important matter in this connection, as it is quite possible that the ordinary kinds of bacteria present in an oyster at its death might normally prevent any appreciable growth of typhoid germs. The proposition from this standpoint certainly ought to be thoroughly studied.

RESISTANCE OF TYPHOID GERMS TO HEAT.

While typhoid germs form no spores and are killed by heat, it is not probable that heat as ordinarily applied in cooking oysters is nearly as great a safeguard against infection as is believed to be the case by many. Thus, Nevin[31] recognizes this in reviewing the data secured at Manchester, and Herdman and Boyce[42] advise that oysters should be *sufficiently cooked*, that is, raised to the boiling point and kept there for at least ten minutes. Clark and Gage[66] found that while exposure for five minutes to a temperature of 55° C. killed the great majority of typhoid germs, a few survived a temperature even of 80° C. In some interesting experiments made by Hill[72] it was found that the cooking of oysters, as ordinarily practiced, usually, but not invariably, killed typhoid germs.

An instructive report along this line of thought is that by Dr. Hamer[73] producing plausible evidence for attributing an out-

break of typhoid fever in certain districts of London, late in 1903, to *fried fish.* In Health Officer Murphy's letter of transmittal reference is made to similar outbreaks officially reported in 1898 by Health Officer Annes of Huddersfield, and in 1899 by Health Officer Williamson of Sandal Magna.

RELATIVE VITABILITY OF B. COLI AND B. TYPHOSUS IN WATER.

The longevity in water of these two species of bacteria is considered by bacteriologists to be quite similar. B. coli is believed by some to be slightly more hardy and to live a trifle longer[66] in water, although Houston[54] found B. coli only after seven or eight days upon making a test with pure sea water artificially infected wih B. coli.

So far as this feature is concerned, the prevalence of B. coli appears to form a satisfactory index for indicating pollution in shellfish and in the water surrounding them.

SANITARY CONDITION AS SHOWN BY INSPECTION OF BEDS AND FATTENING GROUNDS OF OYSTERS AND OTHER SHELLFISH.

During the past ten years it is safe to say that a majority of the more prominent oyster beds, fattening grounds, etc. in this country and elsewhere have been examined with considerable care either by official sanitary inspectors or by those who are competent to form a reliable general opinion as to their sanitary significance.

Similar attention has also been given to other shellfish, especially clams, the life history of which is more or less similar to that of the oyster. The reports of the Rhode Island Commissioners of Fisheries for 1899 and 1900 contain many interesting features about mode of growth, etc., of clams, particularly of the soft shell variety.

Sanitary conditions can be adequately decided upon when the surroundings obviously show either freedom from all pollution or when the sources in question are very seriously and objectionably polluted. Unfortunately, many oyster layings come within the intermediate class, generally spoken of as "doubtful;" and about which it is difficult to arrive at a correct and reliable opinion as to the probable degree of pollution on some occasions. Concerning this doubtful class it is to be stated that information should cover reliably a wide range of

conditions as to wind, weather, currents, and in general take into account all of the physical conditions both subjectively and objectively which bear a relation between population serving as a possible polluting factor and the body of water or beds serving for the cultivation of oysters or other shellfish.

Dr. Bulstrode in his classical report[11] "On Oyster Culture in Relation to Disease," published in 1896, presented the first comprehensive record of the condition of practically all the oyster layings of the English and Welsh coasts. In these sanitary surveys very careful attention was paid to the various physical factors involved in the premises, and which taken collectively record in full what the English sanitarians speak of as the "topographical conditions." Numerous maps were included in Dr. Bulstrode's report to facilitate an understanding of the actual conditions found. To appreciate fully the contents of this excellent report it is necessary to refer to the original. Here it is sufficient to say that many of the oyster layings were in such sanitary surroundings as to make it obvious to the investigator that the oysters and water from these sources were not of a perfectly safe hygienic character.

The State Board of Health of Massachusetts for the past five years has been giving much attention to this question. The report of these investigations, bearing directly and indirectly on all phases of this matter, has not yet been published. It is of interest, however, to note that in connection with some of the bacteriological reports[66] they separate the sources from which shellfish were taken into the three general classes as above mentioned, and that the polluted and doubtful sources form a substantial proportion of the total, as indicated by the following table:

TABLE No. 7.

	Number of Sources.	
Character of source.	Shellfish.	Sea Water.
Not polluted	15	10
Doubtful	22	19
Polluted	6	4

An idea of the location of these several classes of sources is indicated in a special report[74] of the Board to the Massachusetts Legislature in May, 1902.

The oysters taken from the Providence River and Narragansett Bay, below the city of Providence, R. I., have been studied

by Dr. C. A. Fuller[75], who has found that there are several oyster beds within a comparatively short distance of the outfall discharging the sewage effluent from the chemical precipitation works of the city of Providence.

Reference has already been made to the former pollution existing in the fattening beds in the neighborhood of Atlantic City, N. J., but which unsanitary conditions were corrected by order of the City Board of Health[26] several years ago.

Dr. Brown[76], Medical Inspector of the Local Government Board of Ireland, has made a comprehensive report upon all of the principal oyster layings on the Irish coast. This important work was done along lines similar to that by Dr. Bulstrode. In general it may be said that a considerable number of the principal oyster layings showed objectionable sanitary conditions with reference to possible or probable sewage pollution.

Dr. Bensel, Sanitary Inspector of the Board of Health of the city of New York, records[33] the fact that many of the oysters taken from the general vicinity of New York City come from unsanitary sources, referring more particularly, however, to the floats and houses in which the oysters are bloated and bleached.

Reference has already been made to the contamination of portions of Jamaica Bay[27] in the vicinity of Lawrence, L. I.

In regard to the Great South Bay, on the southern coast of Long Island, from which the so-called "Blue Point" oysters come principally, the last report[77] of the U. S. Fish Commissioner records opportunities for pollution, especially in the floats near shore, although the oysters actually analyzed were free from sewage pollution.

In the recent report[78] to the New York Legislature of the New York Bay Pollution Commission it is stated that about 1,000,000 bushels of market oysters and clams are taken annually from the lower New York Bay (below the Narrows) almost exclusively from Gravesend Bay (Kings County) and the southeast side of Staten Island (Richmond County). These shellfish, valued at about $900,000 annually, consist largely of oysters taken from private areas. The industry appears to be increasing, as the extent above stated is 30% to 40% greater than that given for 1901 in the report[79] of the U. S. Fish Commission. The New York Bay Pollution Commission speaks of the present pollution of the Bay as distinctly measurable,

although not great; and further states that most of these shellfish beds are free from dangerous pollution, though some of them are found to be nearer sewer outfalls than is wise or proper This commission also adds that analytical data show the water from the "drinking grounds" to be more polluted than that from the natural beds.

BACTERIOLOGY OF COMMERCIAL SHELLFISH AND ASSOCIATED WATERS.

Although much work has been done upon this subject, the evidence has not yet become clearly enough crystallized so that bacteriological data by themselves can be utilized practically by sanitary authorities in securing a better control of the shellfish placed upon the market.

At the outset it is necessary to consider that the oysters and other shellfish are not cultivated at long distances from the coast where the waters are comparatively pure, as already indicated, but that they are grown comparatively near the shore at depths which enable them to be dredged, and where food is also available for their growth. This is especially true of the drinking grounds where they are bloated and bleached.

The evidence seems to be quite conclusive that oysters grow and fatten more readily in sewage polluted water than they do in pure water, with its relatively sparse organic food.

Data are available in numerous instances showing the effect of sewage discharged under conditions where the pollution is so great that the oysters and other shellfish should not be cultivated there. But the evidence is very meagre in showing precisely what slight amounts of sewage, if any, may reach waters in the vicinity of oyster layings and at the same time allow the oysters to be of satisfactory sanitary quality at all times.

From what has already been said it is apparent that sewage bacteria (including typhoid fever germs) disappear quite rapidly after their entrance into large bodies of water. This point is illustrated by the following table, showing the comparative numbers of bacteria at different distances from one of the two principal outlets in Boston Harbor for the discharge of the sewage of the metropolitan district of Boston[80].

TABLE No. 8.

Distance from Deer Island Outlet.	Bacteria per cubic centimeter.
0 (at outlet)	2,240,000
500 feet	121,000
1000 "	35,000
3000 "	1.800

Even more instructive and interesting are the records given in the next table, from Prof. Clowes' report[81] to the London County Council, showing the rapid disappearance of the great majority of the sewage bacteria entering the lower tidal estuary of the Thames below the sewage precipitation works of the metropolitan district of London. Shortly after the open sea near Nore Light is reached it is seen that the numbers become comparatively very low, approximating those found in the German Ocean. This observation is still more interesting by virtue of the fact that in the Barrow Deep, about fifteen to twenty miles from the Nore Light, there are discharged on an average each day about 7,000 tons of sludge taken from the London sewage works, each cubic centimeter of which contains about 130,000,000 bacteria.

TABLE No. 9.

Locality.	Distance from Crossness (miles).	Bacteria per cubic centimeter.
(Effluent of sewage works)	.0	7,442,857
Mucking light	21.3	4,837
Mole Haven	24.3	3,431
Chapman light	27.0	1,662
Yonklet Creek	29.5	711
Southend pier	31.5	379
Garrison Point	33.5	381
Nore light	35.8	186
Below the Nore	39.3	145

It is needless here to record in much detail the analytical results of the several thousands of oysters and other shellfish which have been examined bacteriologically in various laboratories, especially those in Great Britain and in the United States. In brief it may be said, as already mentioned, that the results of bacteriological analyses show very satisfactory confirmation of the results of careful sanitary surveys of existing local conditions when those conditions show clearly either the absence of pollution or the presence of well-defined pollution.

In regard to the intermediate class, where pollution is doubtful, the bacteriological evidence is of importance and in

general the analytical data are in harmony with the results of sanitary surveys. This is not always true, however, as in some instances, particularly in such exhaustive observations as those made by Dr. Houston[68] in England and by Prof. MacWeeney[76] in Ireland. It was found that occasionally bacteriological data were interpreted on too rigid lines, and in other instances they gave a clue to polluting factors which were not noted during inspection.

Speaking generally, it is of interest to quote from Prof. Houston's report[68], that "experiments show that B. coli or coli-like microbes can not only be practically always isolated from a mixture of ten oysters derived from layings which, judged from the topographical point of view, would be considered either above suspicion or at least remarkably clear from pollution; but also that such microbes can easily be isolated from each individual, or at all events in a great majority of the ten oysters experimentally tested." Thus it is seen that the oysters are quite generally grown in England under conditions where some intestinal bacteria are present, and it becomes necessary to measure the sanitary significance of the numerical contents of B. coli in the oysters, and also the relative value of allied factors in order to arrive at the degree of probable pollution.

Huston's[68] quantitative analyses indicated that oysters taken from various layings contained numbers of B. coli or coli-like microbes ranging from 10 to 1000 to each oyster, the volume of which varies ordinarily is from about 10 to 15 cubic centimeters. He found that the contents of the stomach were more likely to show the presence of B. coli that the shell water, which may bear a direct relation to the water surrounding the bed at the time of removing the oyster. For this reason it seems desirable to cut up the oyster and test the entire liquid which flows or oozes from the shell and body. He suggests two provisional standards, one of which he calls a lenient standard and the other a stringent one; by the former he considers as polluted an oyster containing more than 100 B. coli or coli-like microbes per oyster, and by the latter he puts the limit at 10 per oyster. The Royal Commission[28] in summarizing the results states that future data are required before accepting any standards which would justify condemnation.

One feature has come out very prominently, and that is that the test for B. coli should be made very thoroughly[68] to establish their indentity[76] with those coming from the intestines of men and animals, and that these tests should not be allowed to rest on partial[66] or presumptive[78] laboratory[53] data[39].

A very valuable and instructive set of observations on the bacteriology of oysters from polluted sources recently published by the United States Fish Bureau, is that by Prof. C. A. Fuller[82], who found in the Narragansett Bay that the B. coli contents of oysters gradually lessened as the distance increased from the outfall of the Providence sewage precipitation works, and that there were no observed B. coli in oysters eight miles or more distant from the outfall and away from the source of pollution. This paper also contains a very well prepared review of the literature on "oyster infection."

POLLUTION ON THE OUTSIDE OF OYSTERS.

Naturally there is much sediment including bacteria which is deposited from the water on to the beds in which oysters and other shellfish grow. From the sanitary standpoint it is significant that in the investigation of the outbreak of typhoid fever at Lawrence, L. I.[27], Dr. Soper found by analysis that while 20% of the oysters were certainly polluted on the inside, as many as 70% were polluted on the outside of the shell. The widespread significance of this is that as the oysters are placed on the market, polluting material from the shells of a few oysters very likely, under some circumstances, might seriously pollute oysters which otherwise were perfectly safe. Whether or not this is generally true, or applicable only to the particular conditions in question needs further careful study.

RELAYING OF OYSTERS.

For many years it has been the custom in France to relay oysters in disgorging tanks for a short time with the view to causing the disappearance of pathogenic bacteria before the oysters are placed on the market. This proposition was investigated in 1895 by Professors Herdman and Boyce[83], and as a result of their observations they recommended that before the oysters are placed on the market they should be allowed to remain for a short time in water of unsuspected and well es-

tablished purity. There is unquestionably much merit in this proposition, as was testified to by a large number of competent observers in the hearings held by the Royal Commission on Sewage Disposal. As to the period of time required for polluted oysters to free themselves from all objectionable bacteria, the evidence is not conclusive. Most observers think that it would be safe to make the period two weeks, while a few prefer a period of three or even four weeks. The experts for the Royal Commission, however, at the time the last report of the Commission was published had made comparatively few experiments. Taking everything into consideration, the Royal Commission[28], while recognizing the importance of the relaying of shellfish, not only from the point of view of public health but also from that of the oyster trade, did not feel disposed to committing themselves upon the practicability of the method, but strongly recommended further investigation of the matter.

SUMMARY.

Effects of Pollution.—There seems to be no room for doubt about typhoid fever and other intestinal diseases being produced to a limited degree by oysters and other shellfish taken from polluted waters. While some of the evidence is not above question and the data are extremely meagre for basing an opinion as to the effect of polluted shellfish upon the general prevalence of typhoid fever either upon a single community or upon a whole country, yet the English studies show that it is material and sufficient to call forth more study for means of prevention. Those who do not recognize any relation between pollution of shellfish and the causation of disease either have not looked into the matter or have biased views for commercial reasons, although it was recently rumored[84] in this country that a French commission had reached the conclusion that oysters could not transmit typhoid fever. Regarding this reference to the French commission, coming by way of consular reports, it is found upon consulting the original reference[85] that Prof. Giard's report is sound and conservative, according to general evidence. He concludes that typhoid fever may be transmitted by polluted oysters, although he believes that some of the cited cases are based on questionable evidence. He also states

that the bacterial diseases of the oyster are not transmitted to man.

Oyster Cultivation in Grossly Polluted Waters.—There is absolutely no room for doubt about this being an unsanitary condition of affairs, and one which in the interest of all concerned should be prohibited by law, with proper authorities placed in a position to see to it that this practice is not allowed to continue.

Shellfish Cultivation in Unpolluted Waters.—As a considerable portion of the oysters cultivated in this country come from beds which are practically above suspicion on hygienic grounds, the interests both of the consumer and of the trade require that such sources should be accurately and honestly certified to in a manner similar to "certified milk farms," and by authorities whose technical ability and honesty are above question. The technical advisers of such authorities should be thoroughly trained in engineering, chemistry and biology in all of the various applications to water pollution as associated with the shellfish industry.

Shellfish Cultivation in Moderately or Slightly Polluted Waters.—This is the most difficult by far of the various conditions which should confront suitable authorities, as, from what has already been said, it is out of question to base an adequate opinion upon a single inspection or upon a limited number of analyses, on account of such data not being representative of all conditions met with, and therefore perhaps misleading to a serious degree. Improved methods of study of this problem are very urgently needed, and the results of such improved methods should be applied most exhaustively in order that this matter may be clearly put on a basis fair to the consumer and fair to the oyster trade. One of the principal topics requiring thorough study is the practicability of relaying oysters coming from slightly polluted sources in pure water under such conditions and for such a period of time that the objectionable bacteria may be certainly eliminated.

Relation of Shellfish Pollution to Sewage Disposal Problems.—This matter has not yet been considered other than in a superficial way in this country, but it is clear that the time is approaching when the relative aspects of these matters must be carefully weighed. Speaking generally, it seems apparent[86] that where small sewage disposal projects are associated with large shell-

fish industries, the latter as a business proposition should not be injured or destroyed when a relatively small sum of money produces a satisfactory purification of the sewage. On the other hand, where the sewage disposal question involves a very large center of population and its corresponding cost for purification beyond the point of preventing gross nuisances, then it seems that the small shellfish industry should become subservient to the larger public interests, and be abolished. Where the relative money values of the shellfish industry and of the sewage disposal question approximate each other, it becomes a matter for careful consideration and adjustment for each locality.

Nature of Supervising Sanitary Authority.—In this country the question of polluted shellfish rests largely with the local Boards of Health, who have the authority to prohibit the sale of such food within their city limits. Naturally there are not many boards equipped with technical facilities to do much with this question. State Boards of Health when directly authorized by special legislation may take up the matter on broader lines, as in the case of Massachusetts. The general supervision of the shellfish industry in the United States, however, comes within the jurisdiction of the State Fish Commissions, who as yet have done very little with sanitary matters. To handle the matter adequately, it is obvious that further legislation is required, and differing, quite likely, in different states.

Much interesting discussion on this matter is contained in the fourth report of the Royal Commission on Sewage Disposal, which recommends a new central authority, thoroughly equipped to take up all phases of this matter in Great Britain, and which in turn along executive lines would work through the local River Boards.

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DISCUSSION.

Dr. George A. Soper.—Mr. Fuller's paper is regarded by the speaker as the most valuable digest which has appeared concerning an important aspect of the oyster-typhoid question. Among its several objects, it seeks to answer the question, Are shellfish liable to be the carriers of typhoid germs, and if so, under what circumstances? Mr. Fuller's answer is the answer of every sanitary expert who has given intelligent study to the matter; shellfish which are grown or temporarily immersed in sewage-polluted water undoubtedly are at times the bearers of the infectious virus of typhoid fever.

How much sickness is due to shellfish infected by sewage and just what steps should be taken to prevent the spread of typhoid in this manner, are matters upon which Mr. Fuller has not attempted to express a definite and final opinion. He has given the most important facts, taken from scientific investiga-

tions into the conditions under which shellfish may become infected, but he has left it largely to others to propose the practical means by which the sanitary evils which exist may be corrected, stating merely the unassailable position that, when a discharge of sewage threatens to pollute oysters intended for market, either the oysters or the sewage must be taken care of in such a way as will not permit of their coming together.

Being so largely a compilation of well established facts, most of the paper affords little debatable ground. As a whole, however, it gives an excellent starting point for a discussion of the principles, plans and policies which should underlie work for the prevention of typhoid through shellfish, and it is in directing his remarks to this aspect of the subject that the writer believes he may most usefully contribute to the discussion. The suggestions made are not offered as a solution of all the difficulties attending the subject, but they are presented with the object of eliciting free discussion.

The amount of typhoid fever which is caused throughout the country by infected shellfish is not even approximately known. Statistics do not show that there is an unusually large amount of typhoid in localities where it would be expected if polluted shellfish were a very prolific cause of disease. The typhoid death rate for most of the large sea-board States and for the Middle Atlantic States are comparatively low.

At the same time, it must be remembered that statistics are a poor guide to the prevalence of typhoid fever under any circumstances. There is always more of this disease than is reported. The total number of cases of typhoid which may exist may be manyfold the number officially known to the health authorities. It is one of the leading defects of our public health administrations that typhoid fever is reported neither accurately nor promptly.

It is unfortunately a fact that the causes of most cases of typhoid are not satisfactorily traced, so that even if every case were officially reported, it would be impossible for us to know how many were attributable to shellfish. The greatest laxity in this direction exists with respect to sporadic or scattered cases of typhoid fever, and it is precisely this type which is usually produced by infected shellfish.

Notwithstanding these defects of statistics, however, there

seems reason to suppose that the largest consumers of oysters, the oystermen themselves, suffer more than most persons from typhoid fever. According to the United States Census of 1900, the typhoid fever death rate, reckoned on the basis of one hundred thousand population, is high among men collectively grouped as sailors, pilots, fishermen and oystermen.

The reported death rate in this class for 1900 was 67, as compared with a rate of 38.8 for the total population in the registered areas of the United States. Too much reliance should not be placed upon these figures, however, since there is considerable difference in the habits of the several members of this group and they may all be exposed to typhoid for an unusual extent in other ways. Cases of typhoid fever have been seen repeatedly by the writer among oystermen and their families under circumstances which left no room to doubt that infected shellfish have been the cause.

Owing to their wide distribution, it is not likely that the infectious nature of shellfish from any locality is often discovered. In an investigation of an outbreak of typhoid fever in the vicinity of Lawrence, N. Y., in 1904, it was found that the local consumption of oysters, from certain infected grounds and storage places in the vicinity, was about one-half of one per cent. of the total output from that district. The local consumption gave rise to twenty-one cases of typhoid fever. The oysters which produced the local outbreak were apparently fair samples of the larger quantity which was shipped off. From this it would appear that several thousand cases of typhoid fever may have been caused among the consumers of the shellfish which were sent away. Commenting on the possibility that a large number of typhoid fever cases may have been caused by the consumption of infected shellfish from this vicinity, the official report of the investigation of the outbreak says: "At first sight, one might think that so much typhoid fever from a single cause would promptly lead to the discovery of that cause. Further thought, however, shows that this would not be likely. Several thousand cases of typhoid could easily occur without drawing suspicion to these oysters and clams. The shellfish from this source are shipped to widely separated points—some are said to go to Enrope. Three or four thousand cases of typhoid , scattered among so many people over so

large an area at a season when typhoid is expected to be more or less prevalent, would scarcely attract attention."

It is not believed by the writer that this number was actually attacked, but that many more suffered than were known seems extremely probable.

The number of cases of typhoid known to be annually produced by oysters or clams in any vicinity, even though very small, should not be considered as the measure of the need of protecting the purity of the shellfish. No known cause is too insignificant to call for removal.

It is unfortunate that there is no way by which a consumer can infallibly tell whether raw oysters which are placed before him are infected or not. The writer has seen polluted shellfish which bore every appearance of being wholesome. Experts can sometimes tell by the appearance of the shell whether an oyster has been grown upon a hard or soft bottom or in shallow or deep water, but there is no easy tell-tale of pollution which can be relied on.

Nor is any measure of precaution which can be taken at the table capable of rendering infected oysters innocuous. Tomato catsup, horse radish, lemon, red pepper, and other condiments which are often used upon oysters are not capable of destroying the germs of typhoid fever, when present. The writer has seen a case of typhoid which was produced by oysters eaten in the form of an oyster cocktail. It is necessary to cook an oyster thoroughly in order to destroy its harmful properties.

Apparently, protection from typhoid fever through shellfish must lie chiefly with the Board of Health, State Commissions in charge of the shellfish industries, and with the oystermen themselves. The nature of the regulation possible by Boards of Health has been a question of debate in some quarters. In the writer's view, it should be possible for a local Board of Health to control the purity of the oyster supplies in much the same way that the purity of milk supplies can be controlled. Local boards act under special sanitary ordinances, or general health laws, which give them authority to seize and destroy unwholesome food, and there appears to be no reason why this legal authority should not be used advantageously in controlling the quality of shellfish. There would only be the need of providing that a given lot of shellfish were unwholesome to give the local board

ample power to destroy them or prohibit their sale. The difficulty here would be to prove that the shellfish were unwholesome.

Mr. Fuller has suggested tests by which the purity of oysters can be determined. In the hands of experts, these should prove of much value, but there are limitations to their use. By the time that a lot of shellfish which are suspected of having been the cause of typhoid fever can be subjected to analysis, from two to three weeks will in all probability elapse from the date of infection, during which period the germs are likely to disappear,—if, in fact, any of the original oysters can be found and examined. Furthermore, local Boards of Health, except in municipalities of considerable size, are not equipped for bacteriological work or do not know how to make arrangements for having it done.

Where cases of typhoid fever are traced to shellfish from a given community, suspicion may well attach to that source in the future, unless there is excellent reason to suppose that proper preventive measures are taken. Such sources should be constantly watched. The taking of shellfish from places known to be polluted should be prohibited.

In coming to a decision as to the probability of pollution, the writer is much impressed with the value of a competent inspection of the sanitary conditions under which the oysters are produced. In an investigation of the shellfish grounds situated throughout the entire length of the Irish coast, Profs. T. J. Brown and E. J. McWeeney* found that the value of a sanitary inspection of the source of shellfish and careful bacteriological analyses of them were about equal. In a large majority of instances, there is no difficulty in ascertaining whether producing grounds, storage places or drinking places are polluted.

It might seem that another way in which local boards could control the purity of shellfish would be by restrictions placed upon the production and handling of shellfish intended for shipment for consumption at distant points; but here we meet with the necessity for sanitary control under circumstances which would probably not appear to be sufficiently imminent and pressing to the local board to insure its action. Sanitary restrictions of the kind necessary might conflict with a profitable

*Report of Local Government Board for Ireland, 1903.

local enterprise, in which event, the local board would find it difficult to enforce the preventive measures demanded.

So far, no way has been found for the National Government to control the purity of shellfish, and desirable as this form of regulation appears from some standpoints, it does not seem likely that it will soon be brought about.

In the writer's view, the State Board of Health is the proper authority to control the sanitary conditions of shellfish production. In Massachusetts, the State Board of Health has, as we are informed, shown an active interest in this subject and the action which it took in 1904, in connection with the production of shellfish from New Bedford Harbor, shows what can be done in this manner. Finding that shellfish taken from certain sections of the harbor of New Bedford were apt to be polluted with sewage, the State Board of Health requested that branch of the state government which has supervision over shellfish, the Commissioners of Fisheries and Game, to prohibit the further digging of shellfish from the affected areas. This request was acceded to. The fishermen were warned that after a certain date it would be illegal to take clams from a section of the harbor which was definitely described. Immediately following this, there was a marked falling off in the number of shellfish diggers, but they soon returned. Thereupon, on August 29 and 31, 1904, the Commissioners of Fisheries and Game caused the arrest and conviction of twenty-six men for digging shellfish within this area, after which there seems to have been no difficulty in restricting the production from polluted grounds.*

The suggestion made by the Royal Commission on Sewage disposal,† that all beds and storage places be licensed and that dealers be restricted by law from selling oysters from any but licensed places, seems to be an excellent one. There is no obvious reason why some such plan should not be followed in some sections of the American coast, at least, under the jurisdiction of the various shellfish commissions assisted by the State Boards of Health.

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*Annual Report of the Commissioners of Fisheries and Game, Massachusetts, 1904.

†Fourth Report Royal Commission on Sewage Disposal.

Although some have thought that a further examination of this subject might show the necessity of extensive sewage purification systems and the diversion of sewage from municipalities to points remote from centers of shellfish industries, the writer considers that in most cases it will be the oyster business and not the sewage which will require to be removed. In some cases it will be difficult to decide between the two.

The most promising outlook for the initiation of better sanitary conditions in the oyster business lies, in the writer's view, in the hope that the fishermen themselves will soon appreciate the need of affording their customers protection from the small but unnecessary danger of typhoid to which they are now exposed. It would seem to be a distinctly desirable business proposition for the oyster growers voluntarily to avoid polluted waters, and to place upon the market shellfish which can, by every test, be shown to be pure. If an oyster scare should then occur, a fortune would await the oysterman who could afford to call public attention to the sanitary ways in which his oysters were produced and marketed.

Dr. Henry Leffmann.—I desire to express my personal thanks to Mr. Fuller for this timely and well-prepared paper. It is a most valuable summary of the trustworthy data on a topic of great importance in practical hygiene, and one to which public attention has not been much directed. Experience has fully demonstrated the large part that raw foods play in the distribution of disease. Water, milk, fresh vegetables and shellfish are largely consumed raw and are all common and frequent sources of disease. The general indifference of even intellignt members of the community to these dangers is noticeable, and it will only be by such papers as Mr. Fuller's that an awakened interest will bring about reforms. Even with this progaganda, I fear that more such sad experience will be needed before the reforms will be thorough and far-reaching.

I have had, through the courtesy of the author and the interest of the Secretary of the Institute, an opportunity to see the proof of the paper, and am, therefore, familiar with many of the details that the author merely outlined or suggested in his remarks this evening.

I had an opportunity through the courtesy of the special

committee appointed by the Atlantic City Academy of Medicine, to examine, in company with Dr. A. C. Abbott, the circumstances under which typhoid fever was distributed by oysters in Atlantic City in 1902. The committee worked out the facts thoroughly, and Dr. Abbott and myself were pleased to endorse its view.

Briefly, I may say that, in this case, the oysters were placed in a crib that was located near the junction of the Beach Thoroughfare with an artificial channel termed the Penrose canal. The object of this canal was to cut off some of the winding portion of the natural channel. The sewage of the city is emptied into the Thoroughfare by a pipe that crossed this canal. During the summer this pipe broke in such a manner as to cause the sewage to leak into the channel and to be swept by the alternating tidal currents back and forth through the crib, The oysters were thus soaking constantly in the sewage-polluted water. Raw oysters are largely consumed in Atlantic City during the summer months.

The result of this was that the city, which up to that time had been but little troubled with typhoid fever, began to show a sharp increase in the number of cases. The active practitioners became alarmed, and at once instituted a searching inquiry. In this they fortunately had the active assistance of some of the local authorities and of the more influential hotel-keepers. It was, of course, appreciated that if the disease became well established the city would be seriously injured in its popularity as a summer resort. The physicians and business men of the city deserve great credit for their prompt acknowledgment of the seriousness of the question, their frank statement of the facts, and their concerted action to prevent recurrence of the trouble.

Concerning general preventive measures I have little to say. The problem is more complex in this country than many others because of the absurd and unscientific system of administration by State government. If ours were a national instead of a federal republic, more could be done. As it is, the jealousies of States prevent concerted action. Petty local pride often sets bounds to reform. I had good occasion to note this when I was a member of the Pennsylvania Quarantine Commission. Very little in the way of reform in the control of food adulteration, water supply, and other matters of public hygiene

can be done until the powers of the general government are extended. Fortunately, the tendency is largely in this direction. The present national administration shows a stronger tendency to centralization than any that has yet been in power, and while this tendency may receive temporary checks, the main evolution will go on.

Papers such as this presented to-night will have far-reaching educational value. I am, however, not hopeful that the oystermen or the oyster purveyors will be very alert in supporting reform measures. I may also say that as far as regards the statistics given this evening, which seem to show a higher death rate from typhoid fever among sailors and watermen, this may be due largely to the practice of these persons in drinking polluted river water and not to eating oysters.

MR. KENNETH ALLEN.—It is not many years since the derivation of typhoid from infected shellfish has been recognized. In Constantinople it was observed by physicians that much of the typhoid brought to their notice among the better classes was associated with the eating of oysters, and on examination these were found to contain the typhoid bacillus. During the past few years there have been a number of typhoid epidemics traced directly not only to infected oysters but to cockles, mussels and clams, and the subject has received close study in France, England and the United States.

The more important facts that appear to be fairly well established are:

1. That the typhoid bacillus is gradually crowded out by the much more numerous saprophytes in grossly polluted waters.

2. That it does not survive at a temperature much below blood heat.

3. That it may live for weeks in sea water.

4. That it tends to die out when taken into the oyster and is eliminated within a few days when placed in clean water.

Oysters taken from a polluted water retain typhoid bacilli longer if kept in the air than in clean water, and are less capable of disposing of them in case of further infection.

The colon bacillus, however, has been observed by Prof. Kline, of England, to disappear rapidly in oysters kept either in air or water. He also found that mussels and cockles, which are relatively important as a food supply abroad, were less ca-

pable of disposing of the typhoid germ, this being found actually to multiply in them at first.

These facts would indicate that the particular danger of infection in the case of oysters is confined to those cases where these are taken from grossly polluted waters—as in the vicinity of sewer outfalls—and eaten raw; and this view is confirmed by the various investigations of cases of infection that have been made here and abroad.

Oysters taken from their natural beds, except near towns, are not often to be suspected; but the general custom of storing and fattening oysters in artificial layings, which are frequently in the vicinity of sewer outlets, should be condemned severely. In an epidemic of typhoid at Lawrence, L. I., last year, Dr. Soper examined ten oysters from various storage floats and found B. coli in 10 cc. in every case. Out of thirty-one cases, over half were directly traced to eating infected shellfish, while the indications were that all originated in this way.

Oysters are taken for the market from the greater length of our sea coast, and with increasing population the protection of this food supply should receive more attention than in the past. The waters of Providence River, Long Island Sound, and Staten Island are noted for their oysters, while receiving the waste products of several million people. The Chesapeake Bay, too, noted for its oysters, receives the sewage of Harrisburg, Baltimore, Washington and other cities, although it should be born in mind that here the populous centers are more remote, and while the oysters are taken from the various bays and estuaries, the discharge from the Susquehanna, Patapsco and Potomac Rivers tends to follow the deeper channel of the Bay.

As it is impracticable to prevent the pollution of water courses near cities the obvious remedy is to prohibit the taking of shellfish from within certain limits that may be defined by the State Boards of Health.

This has been done by the local board in the case of Beach Thoroughfare, Atlantic City, where formerly oysters were fattened for the market. A typhoid epidemic in the fall of 1902 called attention to this fact, resulting in an investigation by the Academy of Medicine, assisted by Drs. Abbott and Leffmann, of

this city. The practice of selling these for the local market has been stopped, but it has been found impracticable to prevent their shipment to cities outside the State.

This brings up the question of inter-state action or control by the Federal authorities. From the fact that 20,000 bushels of oysters and 5,240,000 clams were shipped from this market in 1903, the magnitude of the danger is evident, and the mere suggestion, mentioned by Mr. Fuller, that 10 per cent. of the typhoid deaths in London and Manchester may be due to eating infected shellfish should be sufficient to bring about measures to remedy present dangerous conditions.

Mr. W. H. Clark (Correspondence).—The pollution of shellfish by sewage has, during the past few years, become generally recognized as a subject of much importance, both from the commercial and hygienic point of view. Pollution of this sort and its effect in causing typhoid fever began to be recognized many years ago, as pointed out in Mr. Fuller's paper, but only a small amount of systematic study of the subject has been made until during the past few years. In Masachusetts, while the shellfish industries are of small moment from a commercial standpoint when compared with these industries in other States, the consumption of native shellfish and also of shellfish brought into our markets from other States is very large, and it is evidently of the utmost importance to the people of the State that these shellfish, especially those eaten in the raw condition, be as free from bacteria foreign to themselves as sanitary precautions and laws can make them. As stated by Mr. Fuller's article, a quite extended investigation of this subject has been carried on by the Massachusetts Board of Health during the past few years and most valuable data have been accumulated. In this work not only has the pollution of shellfish areas been carefully studied, but also such questions as the life of sewage bacteria in sea water, the life of sewage bacteria in the shellwater of the shellfish and the life of sewage bacteria in or upon the body of the shellfish when kept under market or other conditions have also been examined into. Besides this, studies of the destruction of the bacteria by the common methods of cooking have been investigated. In the course of this work practically all the shellfish areas of the State have

been examined, nearly 2,000 samples of shellfish from these areas, and shellfish brought into the State from other sections have been tested, and also about 600 samples of sea water examined as an aid in the study of the subject.

As this work is still being continued and no official publication has as yet been made by the Board—with the exception of the communication to the State Legislature in May, 1902,—it is obviously expedient to enter into and explain its details and results here. Enough has been done, however, by us, to show the importance of the subject, the marked pollution of certain shellfish areas, to illustrate clearly the danger of eating raw shellfish from polluted sources and to show the inadequacy of some of the common methods of cooking shellfish to assure complete destruction of pathogenic organism. The work has also shown that shellfish kept under market conditions may be a source of danger to their consumers for many days after collection from the shellfish areas. In several instances the Board has prohibited the collection of shellfish from limited areas within the State, and undoubtedly much more work of this kind will ensue.

Mr. Wm. H. Park (Correspondence).—I have carefully gone over the paper that you are to read in Philadelphia, and agree entirely with your conclusions. From the little work we have done in New York, it seems to me that there can be no question that oysters are capable of communicating typhoid fever. To estimate the number of cases due to oysters is a very difficult, if not impossible, task. Personally, I think the actual number of cases is comparatively small. The danger, however, of such infection is constantly increasing, as the streams in which the oysters are placed become more and more polluted. We are thinking of having all oyster dealers take out a license and compelling them to designate from what places their oysters come. We then hope gradually to inspect the oyster beds and fresh water streams and allow only those to be used which appear to be fairly safe. It seems to me that the dealers themselves should combine in such a way as to make certain that all oysters sold by them are safe. At present a great many people refuse to eat oysters because of their fear of infection. The increased trouble which dealers would assume in getting oys-

ters only from safe places would be more than paid for by the increased sale of oysters known to be safe.

[NOTE BY EDITOR.—Dr. Edward Goldsmith has suggested to the editor that the judicious use of copper sulphate, in extremely minute doses, in the waters of the fattening beds, might wholly eliminate the danger of typhoid infection from the source above discussed.]

A NEW ULTRA-VIOLET MERCURY LAMP.

In addition to the visible radiation, all light contains also dark rays, not perceptible to the eye. These are known either as ultra-red or heat rays if their wave length is greater than that of visible light, or as ultra-violet, actinic, or chemical rays, when of shorter wave length than the visible spectrum. Within the last ten or twenty years, the development of physics and medicine has disclosed certain properties of this form of radiant energy, which are not only highly interesting from the point of view of pure science, but seem calculated to be of great service to mankind. In consequence, the demand has arisen for a practical and comparatively cheap form of apparatus for producing these ultra-violet rays, or as we may term them briefly, "uviol" rays.

The want has been supplied by a modification of the Hewitt mercury vapor lamp, the walls of which are made of a special glass prepared in the works of Dr. E. Yschimmer in Jena.

The new lamp consists of a tube of suitable shape—usually straight—made of special glass transparent to uviol rays, 8 to 30 millimeters in diameter and 20 to 130 centimeters long. Platinum terminals are fused in through the glass at the two ends, and are tipped with carbon knobs, so that each pole may be used either as a positive or as a negative pole. The lamp contains 50 to 150 grams of mercury, according to its size. This mercury not only furnishes the vapor necessary for the working of the lamp, but also serves for starting the luminous discharge and for cooling the negative pole. The dimensions are so calculated that the lamp can be connected up to leads of the usual tension of 220 or 110 volts without undue loss of current.

To light the lamp, it is not enough simply to connect it to the leads, the two poles must be for an instant joined by means of the mercury in the lamp, which for this purpose is tilted so as to allow the metal to flow from the one to the other. When once the discharge is started, it will continue after the mercury has fallen back to its normal position. The lamp being made with carbon poles, the ignition may be effected from the positive to the negative end, or *vice versa*, without injury to the lamp (through disintegration or fusion of the platinum terminals); the negative pole may even be laid bare for several seconds without harm while the lamp is being lighted. When, however, it is to run for a prolonged period, it is imperative that the negative pole be immersed in mercury.—Dr. O. Schott, in *Scientific American Supplement*.

The Adulteration of Foods.*

By C. B. Cochran.

State Chemist to the Pure Food Commissioner of Pennsylvania.

[The lecturer discusses the efficiency of the laws in force in the State of Pennsylvania to insure the public against harmful adulteration.—The Editor.

Less than half a century ago almost the entire population of this country lived upon food that was home-grown and home-prepared. With the exception of a few articles requiring a different climate that our own for their production, such as coffee, tea, sugar, spices and chocolate, the inhabitants of the country lived exclusively upon food of their own producing, while the dealers of the city were supplied with the products of the neighboring farms. Provisions of all kinds were supplied in an unprepared condition and their preservation or preparation for the table was acomplished at the home.

Nearly everyone was personally acquainted with the various manufacturing operations necessary, not only for the proper preservation of the products of the farm, but also for the converting of these products into a variety of articles of food ready for use. Even the products of foreign lands were prepared for use at the home. For example, spices were home-ground and coffee home-roasted.

At that time there was little need for laws regulating the sale of foods, for the opportunities for adulterating on the part of the seller were limited to a very few articles. Moreover, the methods of adulteration had not then been learnd.

With the advance of civilization and the specialization of industries, the preparation of our foods has gradually passed out of the home and into the hands of manufacturers. At the present time, this transfer from home to factory, while not yet complete in its details, is nevertheless so universal that it is felt to a greater or less extent in every household, no matter whether that household represents wealth or poverty, or whether located in city or country.

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*A lecture delivered before the Franklin Institute in Association Hall, Friday, February 10th, 1905.

While this change has brought with it many comforts, and has rendered home life less burdensome and more enjoyable, it has also robbed us of that sense of security in the purity and cleanliness of our foods, which was so greatly appreciated and highly prized by our grandparents.

They in their time lived perhaps even more generously than we of the present, and took pride not only in setting a well-spread table, loaded with finely-prepared foods, but also in the fact that those foods were home-grown and home-prepared.

The housewife of a generation ago was mistress supreme of the culinary art. She found her life's work in the management of her home and the care of food materials, and their preparation for the table formed a large part of her work.

Because of our lack of knowledge of former methods and standards of excellence, as well as the various processes now employed by manufacturers, we are no longer capable of judging whether an article of food is pure or adulterated.

This very ignorance on the part of consumers places them at the mercy of the manufacturers and retailers, who pursue their vocations for profit, and are guided solely by business considerations.

Under the strong competition which now exists, the problem that especially concerns the manufacturers is to produce an article acceptable to the public at as little cost as possible, and to the solution of this problem they devote their energies.

The greater the demand for the products of their factories, and the cheaper the cost of production, the greater are their profits.

Whether the article is pure or whether it is what the name implies is oftentimes a matter of little or no consequence, provided it is salable and acceptable to purchasers. Consequently oleomargarine is found in the market as butter, a mixture of cottonseed oil, and tallow as lard; glucose syrup is made to take the place of honey; cottonseed oil is called olive oil; and milk thickened with glue or some vegetable gum passes for cream. Similar adulterations or substitutions might be named in a large variety of food products.

All gradations of mixing, adulterating and beautifying are practiced by manufacturers until, in many cases, the finished article bears no resemblance to the old-fashioned home product

of days gone by. To make an article salable and to produce it at the least possible cost are the key-notes to success.

The above statement must not, however, be taken as universally true. Most reputable manufacturers cater to the best class of trade, and put upon the market articles of a high standard of purity and excellence, but these same manufacturers, under assumed names, send out from their factories inferior articles of varying degrees of impurity to meet the varying demands of competition that exists in all classes of trade.

As a result of these changes which I have thus far attempted to describe, there has arisen an absolute need for a complete supervision of the public food supplies. A supervision which shall place some limit upon the substitution of cheaper and inferior methods and dangerous materials in place of the standard formerly used in our homes.

Hoping that enough has been said to lead us to see the necessity of some supervision, we will next briefly examine what legislation has been enacted for public protection.

As far back as 1860, the Legislature of this State enacted a law providing a penalty for the sale of unwholesome meat or bread, and also a law prohibiting the adulteration of liquors with substances injurious to health. Again, in 1878, a law was enacted making it a misdemeanor, punishable by a fine of twenty dollars for knowingly selling or offering for sale adulterated milk.

No adequate provision was made for the enforcement of these laws, and consequently they were never put in operation. The word "knowingly" in the milk law of 1878 rendered it of no practical value, as it is next to impossible in cases of adulteration to prove guilty knowledge.

It might be supposed that the demand for the establishment and enforcement of laws prohibiting the sale of adulterated food products would have come from the consumers, since it was for the benefit of the consuming public that these laws were enacted, but such was not the case. The demand for food legislation had, in this State at least, a totally different origin, namely, from the food producers, or in other words, the farmers.

Between the years 1880 and 1885, the markets of this State were flooded with oleomargarine, masquerading under the

name of butter. To such an extent was the imitation article sold for the genuine that the butter markets of this State were practically ruined, and the butter-makers and dairymen were almost driven out of business by the unfair competition to which they were subjected. In their distress they appealed to the Legislature for assistance, and as a result of this appeal the oleomargarine law of 1885 was established.

This law was exceedingly severe inasmuch as it forbade the manufacture or sale of any article in imitation of butter within the limits of the State of Pennsylvania. As a result of this law the few oleomargarine factories in this State were removed, but the sale of oleo. under the name of butter still continued to an extent almost as great as before. As there were no provisions made by the State for the proper enforcement of this law, the Farmers' and Dairymen's Protective Association, of Philadelphia, was organized to undertake the enforcement of the law in the eastern part of our State.

The following incident illustrates the extent to which oleomargarine was made to take the place of butter: In the year 1885, a gentleman bought thirteen pounds of print butter, one pound from each of thirteen different stores in the borough of West Chester. On analysis eleven of the thirteen samples proved to be oleomargarine.

The borough of West Chester is surrounded on all sides by a country population whose chief business is the production of milk and butter. In invading Chester County the oleo. people were pushing their business into the very center of a rich dairy district, and were robbing the farmers even of their own home markets.

From 1885 to 1893 this fight between the farmers and butter-makers on the one side and the oleo. men on the other continued. The struggle, however, acted only as a slight impediment to the business of the oleomargarine dealers. The attacks made by the butter-makers were sporadic in character, lacking in persistence and reaching only a few sections of the State. Moreover, the prosecutions when once begun were in many cases easily settled.

As to the result of this struggle between the butter interests and the oleo. interests the consuming public were apparently very indifferent. In fact, what little public sympathy was mani-

fested, appeared to be with the oleo. people rather than with the butter-makers. Public sentiment so far as it showed itself seemed to condemn the law of 1885 as unjust.

In the year 1893 an Act was passed enlarging the powers of the State Board of Agriculture and authorizing that body to appoint an agent, to be known as the Dairy and Food Commissioner, who should be charged with the enforcement of all laws then existing or thereafter to be enacted relating to the adulteration or imitation of dairy and food products.

In the year 1895 an Act was passed establishing a Department of Agriculture to be organized, and administered by an official, known as the Secretary of Agriculture, who was to be appointed by the Governor with the consent of the Senate. This deprived the State Board of Agriculture of the administration of all laws designed to prevent the adulteration of foods and transferred the office of Dairy and Food Commissioner, with all its duties to the Department of Agriculture.

The same year the Legislature enacted a general and comprehensive law forbidding the adulteration of foods, and gave the Dairy and Food Commissioner power to appoint such agents as were necessary to secure its enforcement, and also made an appropriation to meet the expenses of this department.

The enactment of this law of 1895 and enlarging the powers of the Dairy and Food Commissioner was the true beginning of the war against the sale of adulterated foods in Pennsylvania. By far the greater part of the prosecutions have been brought under this Act of 1895.

In order that we may have some idea of the character of this law I will read the first three sections:

ADULTERATION OF FOOD GENERALLY, INCLUDING ALL ARTICLES OF FOOD OR DRINK. (SEE ALSO LIQUOR, PAGE 60.)

*1. That no person shall, within this State, manufacture for sale, offer for sale or sell any article of food which is adulterated within the meaning of this Act.

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*27 June, 1895, §1. P. L. 317. Manufacture or sale of adulterated food prohibited.

**2. The term "food," as used herein, shall include all articles used for food or drink by man, whether simple, mixed or compound.

***3. An article shall be deemed to be adulterated within the meaning of this Act:

(a). In the case of food: (1). If any substance or substances have been mixed with it so as to lower or depreciate or injuriously affect its quality, strength or purity. (2). If any inferior or cheaper substance or substances have been substituted wholly or in part for it. (3.) If any valuable or necessary constituent or ingredient has been wholly or in part abstracted from it. (4). If it is an imitation of or is sold under the name of another article. (5). If it consists wholly or in part of a diseased, decomposed, putrid, infected, tainted or rotten animal or vegetable substance or article, whether manufactured or not, or in the case of milk if it is produced of a diseased animal. (6). If it is colored, coated, polished or powdered, whereby damage or inferiority is concealed, or if by any means it is made to appear better or of greater value than it really is. (7). If it contains any added substance or ingredient which is poisonous or injurious to health: Provided, That the provisions of this Act shall not apply to mixtures or compounds recognized as ordinary articles or ingredients of food, if each and every package sold or offered for sale be distinctly labeled as mixtures or compounds, and are not injurious to health.

The evident purpose of this law is the protection of the public from imposition and fraud and injury to health. It appears to have been the intention of our Legislature in passing the Act to protect the members of this Commonwealth from danger to life and health as well as from fraud in the purchase of food. This was the first Act to be passed solely for the safety and well being of the consumer. Ten years of experience has proved the wisdom of the Legislature that passed it.

I am sorry, however, to say that the people did not at first appreciate this law, probably because the need of it was not properly realized. Public feeling toward this and other food laws, has, however, undergone a very decided change. Where

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**Ibid. §2. Definition of term "food."

***Ibid. §3. What shall be deemed "adulterated food."

there was at one time a feeling of disapprobation, now there seems to be entire approval. This change I have had an opportunity to observe in magistrates' courts, in grand jury rooms, and in the different attitudes now taken by judges in giving their charges to juries. The vigorous enforcement of the food laws under the present administration has had much to do with changing public sentiment by showing the extent to which food adulteration is carried and the consequent necessity for protection.

Upon whom does the responsibility for adulteration rest? Upon the retailer or upon the manufacturer? Judging from my past experience, which covers a period of about twenty years, I am inclined to the opinion that the two parties are about equally guilty. There has been a strong tendency on the part of the public to hold the manufacturer almost solely accountable for the adulteration of food products. This feeling I am sure is, in part at least, a mistake.

It must be acknowledged that there is a large class of food substances put upon the market for the character of which the manufacturer is primarily responsible. In this list are included spices, cocoas, chocolate, strained honey, maple syrup, canned fruits and vegetables, and in fact nearly all goods put up in packages bearing the name of the manufacturer. If articles of this character are found to be adulterated, it is almost, if not quite imperative upon the manufacturer to protect the retailer from financial loss, for the manufacturer who fails to protect the retailer is sure to lose not only the trade of that one retailer, but also his trade in the town where that retailer is located.

As a matter of fact the manufacturer does, to a surprising extent, support the retailer in case of trouble caused by the sale of goods belonging in the list I have just named. There is another class of articles in the handling and sale of which the responsibility for fraud or deception rests largely upon the retailer. If a retailer is selling oleomargarine for butter, or a mixture of cottonseed oil and beef fat for lard, he usually knows what he is doing and is directly responsible for his acts. The retailer is also responsible for the sale of adulterated articles when he purchases his supplies from irresponsible parties and at prices much below their market value.

Some years ago an agent of the Department collected an unusually large number of very badly adulterated spices in a town in Eastern Pennsylvania. Analysis showed that the samples purchased from different grocers were of the same character and consequently had probably all come from one source. On making further investigation the agent found several tons of these ground spices stored away over a livery stable. Analysis of a sample taken from this stock showed that he had found the source from which the grocers had obtained their supplies. It was also found that the grocer had paid for these goods less than one-half the price necessary to buy pure spices, even of inferior quality.

While this is an unusual occurrence it is not entirely unique. Similar events have been observed in sufficient numbers to lead one to think that the manufacturers oftentimes find very enthusiastic allies among the retailers.

Many retailers are more than ready to cater to the public ignorance, or in other words, to deceive the public. They supply to their customers the cheapest articles they can buy, regardless of their character, so long as they are salable.

It is far easier to sell a given article of food at a low price than at a high price, even though it may be at a great sacrifice of quality. In certain markets a mixture of glucose and starch paste, colored and flavored with a little apple jelly, will find a ready sale under the name of currant jelly at a price which will furnish a good profit, while the genuine article could not be sold at a price that would pay for the handling.

Many retailers recognize this desire on the part of the consumers to buy cheaply, and wishing to take advantage of this fact to increase their trade demand the cheapest possible goods from their manufacturer, and they make this demand so imperative that even the most honest and reputable of these manufacturers are forced to yield, to some extent, at least.

Because there is a demand on the part of the public for cheap provisions, and because this demand is not attended with a proper discrimination as to quality the unscrupulous retailer seeks to enlarge his patronage by supplying low-grade or adulterated goods at low prices, thus underselling his more honest competitor.

In this way a retailer may acquire a patronage which he does

not fairly deserve, and which he would not obtain were his customers more capable of judging the quality of his goods. In reality these apparently low prices are furnishing large profits, and the honest dealer is placed at a decided disadvantage.

In just such cases as this the value of the Dairy and Food Department is most apparent. Not only the consumer, but the honest dealer as well, needs all the protection it can furnish.

I have no fault to find with the retailer who seeks to supply goods at low figures, nor with the consumer who wishes to practice economy, but too often this low figure is a trap to deceive the innocent and economical consumer and thus crime is committed. While the demand for cheap goods may serve as an excuse for adulteration, it is not by any means the real reason for it. Business interests prompt both the retailer and the manufacturer, and the desire on the part of each to make the profits as large as possible is the chief, and perhaps the sole cause for food adulteration.

Whenever a grocer buys supplies from irresponsible parties, or at a figure decidedly below the true market value of such supplies, he should assume the responsibility for the character of the goods he is offering to the public. This, I believe, is the view now taken by the Department on the question.

In closing this part of my address I feel that it is only fair to say that the present administration has with untiring energy waged a vigorous campaign against all varieties of food adulteration.

So far as I have been able to observe, this warfare has been waged without favoritism or malice, and regardless of political, financial, social or business influences.

Retailers, manufacturers, wholesalers, prominent as well as humble, have been summoned to answer charges of selling adulterated food, and in all cases, so far as I have seen, there has been manifest on the part of the attorneys representing the Department a willingness to consider where the responsibility rests.

From the work done in my laboratory I have tabulated a list of frequently adulterated articles. This list includes all the samples of the kind that were analyzed during the past seven or eight years. It does not at all represent the conditions of our

markets for the reason that the samples were taken by agents who were hunting for adulterated articles and consequently collected only samples concerning the composition of which there was uncertainty.

On the other hand this table does not show as high a percentage of adulteration in the samples actually analyzed as it should. Only those samples that were so clearly and distinctly adulterated as to make satisfactory cases for prosecution were placed in the column marked adulterated. For this reason many samples that were more or less adulterated have found their way into the column head pure.

Sample	Total	Pure	Adulterated	Sample	Total	Pure	Adulterated
Butter	1303	626	677	Fruit Syrups .	93	18	75
Beer	102	75	27	Honey	83	39	43
Blackberry Brandy	514	143	371	Hamburg Steaks	205	75	130
Chocolate . . .	251	184	67	Lard	234	119	115
Cocoa	151	128	23	Molasses . . .	62	18	44
Cream of Tartar	127	65	62	Maple Syrup .	106	37	69
Coffee . . .	109	68	41	Olive Oil . . .	96	46	50
Cheese	152	143	91	Spices	595	320	275
Condensed Milk	73	68	5	Wines	256	162	94

Immediately after the passage of the food law of 1895, Thomas J. Edge, then Secretary of Agriculture, caused an investigation to be made in regard to the condition of the food supply then found upon the markets. The analyses made by me at that time showed a very high percentage of adulteration in the following articles: Butter, lard, honey, chocolate, cocoa, ground coffee, cream of tartar, spices, olive oil, canned fruits, jellies, jams, flavoring extracts and cider vinegar. In many of the above-named articles the adulteration was as high as from 50 to 75 per cent. of the total number examined. To illustrate, out of eleven samples of cider vinegar purchased in West Chester nine were not produced from apple juice.

At the present time I believe there is less than one-tenth as much adulteration as existed at that time. I am very much

pleased to be able to say that at no time has there been a very large percentage of adulteration of milk. There was a time, however, when it seemed that the use of milk preservatives was about to become quite general. The enforcement of the law relating to this subject nevertheless averted this impending evil. During the past summer about 3 or 4 per cent. of the samples of milk and cream examined were found to contain preservatives.

ANOTHER TURBINE ATLANTIC LINER.

Contemporaneously with the completion of the maiden voyage of the first turbine Atlantic liner, the "Victorian," the sister ship "Virginian" was running her speed trials on the Firth of Clyde, when she developed the very creditable speed of 19.8 knots an hour. Compared with the daily records of the fastest Atlantic liners, this performance is not, of course, remarkable; but when we bear in mind that these two ships were designed originally for a sea speed of about 17 knots an hour, it will be seen that the accomplishment of nearly 20 knots on trial is one more tribute to the capacity of the marine turbine to exceed, when pushed to the limit, by a considerable margin the results for which it is designed. The "Victorian" showed a trial speed of a fraction over 19 knots an hour. The first ocean voyage of the "Victorian," which consumed 7 days 22 hours and 50 minutes, was made under extremely unfavorable circumstances, as she started in a gale of wind, encountered bad weather on the way across, and was obliged to go considerably to the south of her natural course, as far south indeed as the latitude of New York, in order to avoid the icebergs, thereby lengthening her voyage by more than 300 nautical miles. Moreover, it was stated by the captain that the boilers gave considerable trouble by priming. The maximum speed reached during the voyage was 16½ knots. The "Virginian" completed her first voyage under favorable wather conditons in 6 days, 22 hours and 45 minutes. This is the fastest record. On the important question of vibration, the officers and passengers appear to be unanimous in stating that it was practically eliminated in these ships. This, of course, does not prove that there will be a similar absence of engine vibration when a liner with turbine engines is being driven at the speeds of 23 to 23½ knots, at which the fastest of the German ships have been driven by their reciprocating engines. But it is fair to presume that even at such high speeds the vibration will be confined to that which comes from the propeller.—*Scientific American.*

COMPOSITE BRICKS OF UNUSUAL STRENGTH.

A test made at Purdue University, Lafayette, Ind., of composite bricks made at Indianapolis, of sand, cement and lime, showed a crushing strength of more than 15,000 pounds, as against 1,500 pounds for an average clay brick and 3,500 pounds for an average faced brick. In transverse strength the composite brick showed a resistance of over 2,500 pounds.

COAL TESTS.

An opportunity has been offered the coal producers of the country to co-operate with the United States Geological Survey in its work of testing the coals and lignites of the United States. This work was begun at the World's Fair Grounds, St. Louis, during the Exposition and will be continued along the lines laid down at that time. The Survey is desirous of securing from operators and others interested in the problems of fuel consumption an expression of opinion as to whether they desire to co-operate in this work. Offers of coal for testing purposes should be addressed to the Director of the United States Geological Survey, Washington, D. C.

It is not possible to promise at the present time that all offers of coal will be accepted, but the plan is to make the investigation as complete as practicable, distributing the work as impartially as possible over the entire country. The distribution of the work will depend largely upon the replies received to the circular which the Survey is now sending out to coal operators and upon the present and possible future development of the coal and lignite deposits of the several States.

The tests will be made for the purpose of determining the fuel values of the different coals and lignites and the most economical methods for their utilization. Arrangements have been made with the manufacturers of the equipment used during the Expositon to have practictlly all of this testing machinery left at the disposal of the Government.

In offering coal for testing purposes, operators are requested to note the following conditions with which it is necessary to comply:

1. The coal must be furnished to the Testing Plant free of cost to the Government.

2. The coal must be loaded under the supervision of one of the inspectors employed for that purpose, who shall be at the same time allowed to visit the working places in the mine to procure samples for analysis.

3. When it is possible to do so, the coal should be loaded in box cars and shipped under seal. Lignites must always be shipped in this way.

4. Where the market requires screened coal, this grade will be accepted for test. The selection of coal is always to be under the direct control of the representative of the testing plant.

5. Where one of the problems involved is the better utilization of slack coal, a carload of slack may be accepted for testing purposes.

6. As soon as possible after the tests are completed a brief statement of the results will be furnished to parties supplying the coal, for their information, but this must not be made public until the results are published by the Geological Survey.

7. Everyone interested in any particular test or in the general operation of the plant is invited to be present at any time, but the official record of the test will not be given out except as indicated in the preceding paragraph.

CHEMICAL SECTION.

(Stated Meeting, held Thursday, January 19th, 1905.)

The Chemistry of Electroplating.

By Wilder D. Bancroft.

[The author presents in this paper the most recent facts relating to the electrolytic precipitation of the metals.—The Editor.]

It is my object to-night to show that many of the peculiarities attending the electrolytic precipitation of metals become clear when we consider the chemistry of the reaction and follow out chemical analogies. For the purposes of discussion we will define a good deposit as one in which the metal comes down in a pure, fairly adherent, reguline form. Except possibly in the case of treeing, a bad deposit apparently is due always to the precipitation of a salt of the metal. This is usually an oxide or hydroxide, but may be a simple cyanide in cyanide solutions. It is often stated that the precipitation of hydrogen makes a deposit bad. There seems to be a confusion here between cause and effect. In electrolytic analysis hydrogen is evolved and yet the deposit remains good. Further, the so-called critical density varies enormously with the size, shape and distance apart of the electrodes, and also with the size and shape of the containing vessel. The most important factor is the rate of stirring. If a solution gives a good deposit at some current density, it seems probable that a good deposit can be obtained at any higher current density provided the stirring is sufficiently rapid to prevent impoverishment of the film at the surface of the cathode. When a deposit becomes sandy or changes to a black powder with increasing current density, the polarization shows that there has always been

the formation of a dilute solution at the cathode. In most cases this leads to the precipitation of an oxide or basic salt, with the usual disastrous results.

If a bad deposit is always due to the precipitation of a salt, the addition of anything that will dissolve the salt readily under the conditions of the experiment will prevent its deposition and should therefore improve the quality of the deposit. I have made a list of the more important additions recommended in the refining, analysis or plating of zinc, nickel, lead, tin, copper and silver. These are given in Table I.

TABLE I.

Zinc.	*Tin.*
Sulphuric acid	Sulphuric acid
Potash	Potash
Ammonium chloride	Sodium pyrophosphate
Ammonium sulphate	Potassium carbonate
Aluminum sulphate	Acid potassium tartrate
Potassium cyanide	Potassium cyanide
Acid potassium oxalate	
Nickel.	*Copper.*
Sulphuric acid	Sulphuric acid
Ammonia	Ammonia
Ammonium salts	Alkaline tartrate
Potassium cyanide	Ammonium oxalate
Sodium bicarbonate	Potassium cyanide
Sodium bisulphite	Sodium bisulphite
Lead.	*Silver.*
Acetic acid	Nitric acid
Potash	Ammonia
Fluosilicic acid	Potassium cyanide
Sodium nitrate	Potassium iodide

All the substances under zinc dissolve zinc hydroxide. The first four under nickel dissolve nickel hydroxide; the sodium bicarbonate probably serves to keep the acidity constant; while the sodium bisulphite occurs only in solutions containing free ammonia. All the substances under lead dissolve lead hydroxide. Stannous and stannic acids are soluble in sulphuric acid, in potash, and in a so-called sodium pyro-phosphate solution; potassium carbonate is added only to neutralize an excess of free acid in stannous chloride solutions; while the cyanide and tratrate seem to be of very little value, unless perhaps at the anode. Under copper, everything dissolves the hydroxide except sodium bisulphite and this is added to cyanide solutions to prevent loss of cyanogen when the copper changes

from the cupric to the cuprous form. All four substances under silver dissolve freshly-precipitated oxide; in addition ammonia dissolves silver chloride, while silver cyanide and silver iodide are soluble in potassium cyanide and potassium iodode respectively.

It is thus clear that there is a simple rational basis for many of the solutions in actual use. It must be kept in mind, however, that the rate of solution is more important than the actual solubility. Thus it is not easy to get a good deposit from an alkaline zincate solution at 20°, whereas it is a comparatively simple thing to do this at 40°, because the caustic soda reacts with zinc oxide or hydroxide much more rapidly at this temperature. It does not follow from this that a higher temperature would necessarily be even better. At 90° the action of caustic soda on metallic zinc becomes an important factor. With copper sulphate solutions, rise of temperature means increased formation of cuprous sulphate, and this must be taken into account. In each of these cases a study of the chemical reactions shows the cause of the difficulty.

We now come to the more interesting side of the question: to the factors affecting the size of the crystals in electrolytically-deposited metals. It will be well to run over briefly what our chemical analogies would lead us to expect, and then we can consider how closely the predictions are fulfilled.

Rapid crystallization of a salt from solution gives us small crystals, while slow crystallization leads to larger crystals. We should, herefore, expect the crystalline structure of the electrolytically-deposited metals to be finer the more rapid the precipitation, in other words, the higher the current density. At high temperatures chemical precipitates are more crystalline than at lower temperatures. Two striking instances of this are barium sulphate and alumina. If we increase the difficulty of precipitation we should expect that the crystals would have more difficulty in reaching a large size. We therefore conclude that we shall get a more nearly amorphous deposit from a dilute solution than from a concentrated one, provided all conditions remain the same. We can generalize this and say that the greater the potential difference between metal and solution the finer will be the elctrolytic deposit. At one time I thought that this could be carried still farther, and that we could say

that neutral solutions would give coarser deposits than acid ones; that oxidizing agents would cause fine deposits and reducing agents coarser ones. Further experiments have shown that this is not generally true and that the effect varies from metal to metal and sometimes from concentration to concentration.

We know that the addition of a colloid to a solution increases the probability of a precipitate coming down colloidal, and that chemically precipitated metals are rarely pure. From this we conclude that addition of a colloid to a solution will make the electrolytic deposit more finely crystalline and that the carrying down of substance with the metal will tend to make an amorphous deposit, always provided that the substances carried down do not spoil the deposit entirely.

We can now consider the experimental results. With zinc sulphate, sodium zincate, copper sulphate, silver nitrate and stannous chloride solutions, the crystals become smaller as the current increases. The silver nitrate solutions were especially interesting. At St. Louis, last summer, the point was raised that it was impossible to obtain a fine-grained deposit of silver from silver nitrate solutions, no matter how high the current density was raised. In our first experiments with silver nitrate it was not possible to detect any effect due to current density. This was somewhat discouraging. Since a silver salt is formed at the anode which increases the weight of the cathode deposit, it was thought that this same salt might affect the crystalline structure of the metal. The experiment was repeated using a porous cup to separate the anode and cathode solutions. We then obtained smaller crystals with higher current density. With twenty amp. q. d. m. the deposit could be burnished.

With an acidified copper sulphate or zinc sulphate solution, the deposit became coarser as the temperature was raised from 20° to 40° and to 70°. With a zinc sulphate solution which was only faintly acid, the deposit was coarser at 70° than at 40° but was coarser at 20° than at the other two temperatures. I suspect that at 20° the slight acidity had no appreciable effect on the deposit, while it became an important factor at 40°.

The effect of concentration is that required by the theory. With zinc sulphate, sodium zincate, copper sulphate, and silver nitrate solutions, smaller crystals were obtained from the more

dilute solutions than from the more concentrated ones. The deposit from the zinc sulphate solutions was coarser that that from the sodium zincate solutions, these last being very smooth. It is a recognized fact that silver and copper precipitate well from potassium cyanide solutions. Silver nitrate in pyridine gives a finer deposit than in aqueous solutions. From sodium stannate solution much smaller crystals were obtained than from a stannous chloride solution.

The addition of sulphuric acid to a neutral solution of copper sulphate makes the deposit much finer. We have not yet noticed a corresponding effect with any other metal and are therefore forced to believe that this is characteristic of copper, in which case it is probably connected with the presence of cuprous sulphate in the neutral solution. This point cannot be considered as settled definitely. The addition of formaldehyde made the metal deposited from zinc sulphate solution finer, while it coarsened that from the zincate solutions. Addition of formaldehyde improved the deposit from copper sulphate solutions, while the addition of a good deal of nitric acid made the copper crystals finer than when deposited from a neutral solution, but coarser than when deposited from a solution acidified slightly with sulphuric acid. An excess of nitric acid makes the deposit from a silver nitrate solution coarser at high current densities and finer at lower densities.

Coming next to the question of colloids we know that the addition of glue to lead fluosilicate solutions improves the quality of the deposit enormously. In the laboratory we have tried the effect of ten grains of glue per liter. With zinc, copper and tin, the crystalline structure was much smaller than without the glue. With a silver nitrate solution we obtain a violet deposit which is apparently amorphous silver. Though we have not yet had time to test this thoroughly, it seems probable that we have here an explanation of "bright" deposits. A bright deposit is one in which the crystals are so small that the deposit is practically amorphous. By using less glue in our silver nitrate solution we could probably get a fairly bright deposit. We have not yet analyzed the silver deposit from a solution containing glue, but it is probably not pure. Carbon bisulphide is the substance most often added to silver cyanide solution to cause a bright deposit, and this bright silver is said to contain

sulphur. When too much carbon bisulphide is present, the deposit is said to become black. I think that it has usually been assumed that this black color was due to silver sulphide; but it now seems possible that a violet colodial silver is precipitated. Jordis states that bright deposits of many of the metals can be obtained from lactic acid solutions. Since the metal deposited from a solution of an organic acid may easily contain carbon, it becomes quite possible that there is an intimate connection between the two facts.

It has been noticed by many observers that a bright or burnished deposit can be obtained when one rotates the cathode and uses high current densities. Those who made these experiments were interested primarily in increasing the current density and they varied the speed of rotation and the current density simultaneously. Consequently, one did not know whether the burnished effect was solely the result of the current density or not. To test this question Mr. Snowdon made some experiments with a silver cyanide solution and a rotating cathode. The current density and speed of rotation were so adjusted that a bright deposit was obtained. Then the speed of rotation was kept constant while the current density was increased. Since an increase of current density would decrease the size of the crystals, the deposit should have become even brighter if the current density were the only factor. As a matter of fact the deposit was distinctly frosted. The only explanation that I have been able to find is that the moment of precipitation there is a polishing effect due to surface friction. If more metal is deposited in the unit of time than can be polished, the metal is frosted. While this explanation may not seem satisfactory to everyone, it does account for the facts, and this is certainly a point in its favor.

It has been noticed that the presence of salts of cadmium, iron, lead and copper interfere with the satisfactory precipitation of zinc. The reason for this is very simple. These metals precipitate before zinc and set up a local circuit which oxidizes the zinc and causes the deposit to become faulty. This local circuit may make trouble in other cases. When we have to plate a noble metal on a less noble one, we usually make use of a striking-bath in which the difference of potential between the two metals is not very great. This keeps down any non-electro-

lytic precipitation to a minimum. When we are depositing a less noble metal on a more noble one, we never bother ourselves about the formation of a couple and we may be thereby led into serious error. Zinc will precipitate nicely on a zinc cathode when it will not deposit well on a copper cathode owing to the evolution of hydrogen. The difficulty about precipitating zinc with a low current density is due chiefly to local action at the cathode. It seems probable that this also accounts for its being so much more difficult to precipitate lithium on a platinum electrode than on an iron one.

Another point of importance to the plater is the adhesion of the deposit. While it has been suggested that an adherent deposit can be obtained only when the two metals can combine to form compounds or solid solutions, this contention does not seem to be in accord with the facts. The surface between two metals is a thin weld and it must show the same strength, no matter how it has been made. In other words, the adhesion of an ideally-made electrolytic deposit will approach that of a casting having the same size of crystals. Presence of grease, of air-bubbles, or of occluded mother-liquor will impair the contact and weaken the joint. If the metal be deposited in a state of strain, the break will come at the weakest point. These are matters of general knowledge in making welds or castings, and they are just as much first principles in electrolytic work. No one seems to have been struck by the absurdity of the statement, to be found in most books on plating, that nickel cannot be plated on nickel, because it will not adhere. If this were true it would not be possible to deposit more than an infinitesimally thin film of nickel electrolytically. While it requires a higher voltage to deposit nickel than copper, nickel does not precipitate copper to any appreciable extent when immersed in a copper sulphate solution. The nickel becomes passive and is probably covered with a thin film of oxide. What is meant is that an "active" nickel containing hydrogen will not adhere to a "passive" nickel. There is nothing surprising or mysterious about this. By making a nickel electrode the cathode in an acid solution for a few minutes before putting it in the nickel bath, Mr. Snowdon has been able to plate nickel on nickel getting a beautifully adherent deposit.

The theory which I have outlined for you to-night has been

able to account for the phenomena due to added salts, current density, temperature, concentration, solvent, colloids, other metals, and cathodes. It has not accounted for the effect of acids, oxidizing agents and reducing agents; but this seems to be due to our ignorance of the chemistry of these solutions.

THE PRODUCTION OF TALC AND SOAPSTONE.

The total production of talc and soapstone of all varieties during 1904 was 91,189 short tons, valued at $940,731. As compared with 86,901 short tons, valued at $840,060, in 1903, this is an increase of 4,288 tons in quantity and of $100,671 in value, due partly to a general increase in the production of talc from all States, but principally to the large increase in the production of fibrous talc in New York. In 1903 there had been a large decrease in the production of fibrous talc in New York as compared with the production of 1902, which was due to long-protracted strikes at some of the paper mills.

Of the 1904 production, 27,184 short tons, valued at $433,331, were obtained from all the States exclusive of New York. This value includes that of the manufactured product made from the talc, as only a small quantity of the product is sold in the crude state. The production came from nine States, and these, together with the number of producers in each, were as follows: California, 1; Georgia, 2; Massachusetts, 1; New Jersey, 1; North Carolina, 5; Pennsylvania, 2; Vermont, 3; Virginia, 2, and Washington, 1, a total of 18 producers.

The production of fibrous talc from New York amounts to nearly double that obtained from all the other States, and almost all of it is used in the manufacture of paper. In 1904 the New York output amounted to 64,005 short tons, valued at $507,400, as compared with 60,230 short tons, valued at $421,600 in 1903. The average price for a ton of talc in 1904 was $7.92, as compared with $7 in 1903, and with $8.65 in 1902, an increase of 92 cents a ton over 1903, and a decrease of 73 cents a ton as compared with 1902.

The importation of talc into the United States has been very irregular and never amounted to much. The quantity and value of the talc imported in 1904 was greater than in any previous year. It amounted to 3,268 short tons, valued at $36,370.

The above facts are taken from the report of Dr. Joseph Hyde Pratt, of the United States Geological Survey. Dr. Pratt's report is now out as an extract from the Survey's forthcoming volume, "Mineral Resources of the United States, 1904."

Mining and Metallurgical Section.

(*Stated Meeting held Thursday, March 4th, 1905.*)

New Methods in the Metallurgical Treatment of Copper Ores.

By N. S. Keith.

[A method is here described for the utilization of low-grade copper ores.—The Editor.]

In many sections of the United States there are vast deposits of sandstone, carboniferous, triassic, and earlier, which contain copper, either in the metallic state, or mineralized as sulphides and carbonates. The chief sulphide is Cu_2S, variously called chalcocite, copper glance, or cuprous sulphide. Sometimes chalcopyrite occurs, more or less mixed or combined with iron pyrites; but comparatively infrequently. In the eastern section of the country these cupriferous rocks are noticeably occurrent in the Appalachian ranges, from Maine and Vermont to the Carolinas.

In the sandstone regions, disconnected from the main range, such deposits have been found, and have been somewhat exploited from the earliest years of the history of the country.

Beyond Maine, along the coast of New Brunswick, there is a considerable tract of cupriferous, carboniferous sandstone at Dorchester. In Connecticut, not far from New Haven, are copper-bearing sandstones. In New Jersey, at Arlington, eight miles west of New York City, are such sandstones of the triassic formation, with intrusive trap dykes and sheets, from which trap the copper impregnations were probably derived.

On the banks of the Delaware River, in Warren County, New Jersey, a few miles above the Delaware Water Gap, are cupriferous rocks, classed as Medina and Oneida sandstones, of an older period than the triassic, and not associated with trap rocks, or other evidences of volcanic disturbances. There are other places in New Jersey where sandstone deposits have had attention given them.

In Adams County, Penna., not far from Gettysburg, there are sandstones which contain not only chalcocite and carbonates, but metallic copper. In this case, as in all of the others, the copper carbonates (malachite and azurite) occur at and near the surface, and are the result of the action of the atmosphere and carbonated waters on the chalcocite and metallic copper.

All of these sandstones are essentially silicious, being built up from quartz grains cemented together by silica from thermal waters containing silica in solution. This silica solution may have been, and probably was, the result of the solvent action of the thermal waters on the sand itself while lying on a horizontal plane, from which position the sandstones have been moved to planes having various dips from their original ones.

The sandstones frequently contain a small percentage of calcium carbonate, or calcium in some other combination, such as the sulphate.

In Virginia, near Virgilina, on the boundary line of North Carolina, there is a mineralized belt of country extending 25 miles north and south in the two States. The country rock is slate, in this slate there are quartz veins and porphyry dykes, parallel with each other, and conformable with the stratification of the slate.

These veins and dykes carry carbonates of copper and chalcocite, with bornite, and occasionally chalcopyrite. These rocks are silicious, as in the other cases.

Besides their contents of copper the rocks at the various points I have named carry gold and silver, in amounts varying from traces to some dollars in value per ton of rock. The copper constituent averages in the several cases at from one per cent. to three per cent. of the weight of the rock; that is, from 20 to 60 pounds per ton.

There are many other places at which like rocks are obtainable; but these serve to illustrate prevailing conditions, and to show the foundation for the methods of treatment which I am about to consider.

In all of these cases the smelting of the rocks to obtain their metals is possible in theory, and practicable under favorable conditions; but these favorable conditions are absent. The unfavorable conditions are:

(1). The absence of, or expense of, suitable fuel at the mines.

(2). The absence of, or the expense of, suitable fluxes, such as iron oxides, iron sulphides, or limestone, at the mines.

(3.) The cost of transporting the rock to the neighborhood of fuel and fluxes.

(4). The "low grade" of the rock. That is to say, the copper, gold and silver are not in quantities enough to yield values sufficient to pay either for bringing the fuel and fluxes to the mine, nor for taking the rock to the fuel and fluxes.

There are places where copper ores and rocks of no higher grade than these are worked at a profit. But they are where the ores are "self-fluxing." That is to say, where the ore itself is composed of materials which naturally react on each other in the furnace to produce slags which are liquid enough to permit the metals to come together, and where the necessary fuel is cheap enough; or, in cases where there are cheaply obtainable suitable ores to admix so as to make a fusible mixture. Then again, the rocks which have their copper in the metallic state can be worked after the methods pursued at the Lake Superior mines, where rock containing less than 15 pounds of copper per ton are mined and reduced at a profit.

But I am to consider the treatment of silicious rocks where the considerations are unfavorable for smelting.

Foremost among the methods which have been tried is that of "leaching." Leaching consists in submitting the cupriferous material to the action of solvents of the copper constituent, and then reducing the dissolved copper from the solution by means of a reducing agent. The rock must first be crushed and ground to a fineness, say that of fine sand, so that the solvent may have access to all of the copper mineral. About the only available solvent of the chalcocite and metallic copper is a solution of ferric sulphate or of ferric chloride. A solution of either of these salts of iron dissolves, though slowly, both chalcocite and metallic copper, by forming copper sulphate or copper chloride, and the ferric solutions are changed to ferrous solutions. These ferrous solutions are changed by exposure to air, by absorption of oxygen, to the ferric state; and are then again usable to dissolve more copper. The copper may then be deposited from its solutions by means of metallic iron, generally scrap, or by means of electricity.

This seems at first glance a simple process. But there are

serious complications, chief among which is the presence of lime, or calcium compounds, in the rocks, as is almost always the case.

The lime acts up to its limit in quantity to neutralize its combining equivalent of the sulphuric acid, or chlorine, constituent of the solvent, and that action is preferential above that on the copper. The only exception to this is when the lime is present as a sulphate, which is seldom. It is generally calcium carbonate.

The next leaching method is to grind the rock to a sand, as before, and then roast it, so as to oxidize its oxidizable constituents. The result then is, if the operation is carefully performed, the formation of oxide of copper in the sand, and of some calcium sulphate, and some calcium oxide, or lime. Then the roasted sand is leached with a dilute solution of either sulphuric or hydrochloric acid. But this has been found impracticable where acids are expensive, and where there is lime in quantity as low, even, as one-half of one per cent. of the rock.

If there be at hand some sulphide ores, as of iron, carrying some copper, say two per cent. of the latter, it may be ground and mixed with the ground sandstone or quartz and roasted as before. Then the lime will sulphated and will not thereafter combine with the acid to its loss in the subsequent leaching.

Having thus obtained the solution of copper, with questionable economy, the method of precipitating the copper therefrom by the use of iron scrap, or pig, is pursued in various localities. This method of precipitation of copper is very old and well known, and is only one of the steps constituting some of the modern methods pursued in obtaining that metal. But, to-day, that step is too costly in most localities. While, theoretically, 56 pounds of iron should precipitate 63.35 pounds of copper, in practice nearly three times that quantity of iron is used. This comes from excess of acid in the copper solution, a waste in itself, uniting with its equivalent of iron; from oxidation of iron; from the formation of ferrous salts; scale and rust and dirt on the iron as purchased, small pieces undissolved, etc. Then the precipitated copper is very impure. It contains on the average about 70 per cent. of copper. The other constituents of this "cement copper," so-called, is iron oxide, sand, and other extraneous matter, which must be removed by smelting.

A better method is this: Having obtained the solution of copper by some method, it is deposited by means of electricity. In brief, this is accomplished by immersing the electrodes of a source of electricity into the copper solution, and causing a graded current of electricity to flow from the anode through the solution to the cathode. In this way, if the strength of the electric current be properly proportioned to the amount of copper in the solution (the electrolyte) at all instants of the time of the operation there will be produced on the cathode a deposit of reguline copper of great purity, and in a commercial scale much cheaper than by iron as above outlined.

But the anode must be insoluble. In sulphate solutions lead stands the action in the bath much better than any other sufficiently cheap material. Carbon anodes do not endure in sulphate solutions, but are practicable in use in chloride solutions, in which lead anodes are quickly chloridized. But lead anodes must be, as far as possible, kept continually in action to prevent them from sulphating. The cathode is generally a thin sheet of copper at the start, prepared by the electrodeposition of copper on a cathode of lead, from which latter it is stripped when thick enough for use.

Under the just-described method it is necessary, in order to economically deposit the ultimate quantity of reguline copper within a required time, to begin the deposition by use of the current at its maximum density between the electrodes, permissible in the production of reguline metal on the cathode, and retrogressively decrease that density as the action goes on, and in proportion to the decrease of the metal in the solution, till, at the end the minimum density of current is in use, and the minimum amount of copper is left undeposited in the solution.

It is not necessary to deposit all of the copper, because the solution will be used again to dissolve more copper, the acid from the deposited copper being freed by the electrolytic action so that it may again combine to form a soluble salt of copper.

It is evident from the above that the source of electricity, a dynamo, is not acting during the time on the average above one-half of its capacity. It was started at its maximum and finished at its minimum.

To obviate this difficulty I have devised the following described apparatus and method: The deposition vats are placed

in series so that the liquid or solution is caused to flow from the first to the last in regular succession. They are also connected with the dynamos in electrical series, so that the electric current flows through all in equal strength in amperes.

As the solution has, in practice, a nearly uniform amount of copper per unit in it as it flows into the first vat of the series, that vat has in it a cathode surface which permits the deposition of about the maximum amount of reguline copper obtainable on that area of surface.

That area is limited by the amperes of current available. In other words, the density of current is such that reguline copper is deposited, but the density of current is less than that which causes the deposition of a brown, sandy deposit.

In the second vat is a larger cathode area. As the same amperes of current flow in this vat, the density of current is less, because the area of cathode is greater. The same amount of reguline copper is deposited as in the first vat, and in the same time, but over a larger area.

The same progressive increase in cathode area is made in each successive vat of the series. The same current flows through all, but its density is less and less through the several vats of the series, so that reguline copper is deposited to the same amount in each, until the depleted solution flows out of the last vat of the series, to be again used to dissolve copper from more rock or ore. In this way the electricity is used most economically.

But none of these leaching methods obtains the gold and silver which almost invariably accompanies the copper. To obtain these leaching by cyanide of potassium solutions might be performed after thoroughly washing the pulp which has been treated for copper. But this will often be found too expensive for the values obtainable.

I have devised and put into successful operation the following described method of treating the silicious copper-bearing rocks which we have been considering. It is based on these chemical and metallurgical facts:

Silica alone is infusible at temperatures at which copper, gold and silver are melted. In those rocks there is not enough iron or lime to act as fluxes for the silica, which last averages 90 per cent., or more, of the whole.

Oxide of iron, and *oxide of calcium,* separately, are likewise infusible.

Copper carbonates, azurite and malachite, when exposed to red heat, are decomposed; carbon oxide is freed as a gas, and cupric oxide remains. If the atmosphere in which this decomposition takes place be a reducing one, say carbon monoxide, then the copper is reduced to the metallic condition by passing of the oxygen of the cupric oxide to the carbon monoxide to produce carbon dioxide. If the temperature be high enough to melt copper that will be found in small metallic globules if the carbonates were diffused in the rock.

Chalcocite, or copper glance, Cu_2S, when exposed to a like heat in an oxidizing atmosphere, as on the hearth of a roasting furnace, is decomposed; the sulphur partly distils off, and is partly oxidized to sulphurous acid, SO_2. The copper is first freed as a metal, and then rapidly oxidized to cupric oxide. If, then, the character of the flame and gases be changed to a reducing nature the copper oxide will be reduced and fused as stated above.

If *carbon,* such as coal, be ground or pulverized, and be projected into a flame in a furnace with free access of air, it immediately ignites and is oxidized to carbon monoxide and carbon dioxide. If the air be insufficient to furnish oxygen enough for the formation of dioxide only monoxide will be formed.

The air admitted with the powdered carbon may be sufficient to form at the first stage of the combustion only carbon dioxide, but as the action continues, the hot particles of carbon absorb half of the oxygen of the dioxide, reducing the latter to monoxide.

The atmosphere resulting from this operation consists of nitrogen, from the air, and carbon monoxide from the union of the oxygen of the air with the carbon. There are, also, small quantities of gaseous hydro-carbons, because of reactions due to the presence of water in the air and in the coal. This atmosphere of hot gases is ready to, and does, take oxygen from hot oxides, and thus reduce them to the metallic state.

The practical, working, furnace in which the several reactions above recited take place, consists of a vertical shaft about

twenty feet high, constructed of red brick with a fire-brick lining.

At the top of this shaft are many holes, or openings, through which the powdered rock, powdered coal and flames from producer gas, or like fuel, are introduced. The bottom of the interior of the shaft is inclined at an angle of about 45 degrees, and this incline is extended into a dust-collecting chamber. This chamber, in turn, connects with another vertical shaft, also with an inclined bottom, dipping toward the other incline. The interior of this shaft is filled with pieces of coke, or small stones. This latter shaft is called the "condensing chamber." Near its top is a sprinkler to distribute water over the coke or stones, after the manner of a gas washer or scrubber. The draft for this furnace is produced by an exhaust fan through a pipe from the top of the condensing chamber. The draft is downward in the first shaft and upwards in the condensing chamber.

The operation by which copper, gold and silver are extracted from the silicious rocks is described as follows:

The rock, as it comes from the mine, is dumped from the cars into a crusher, or a series of crushers, which reduces it to sizes suitable for the pulverizers, into which it is automatically fed, and in them reduced to powder. The fineness of this powder is determined by the diffusion of the copper mineral in the rock; and it should be so fine that the particles of rock and mineral are no longer coherent; but, of course, still mixed. The degree of comminution is measured by sieves, which may be as fine as sixty mesh, or finer, or coarser, according to the above requirement.

At some stage of this process of comminution finely pulverized coal, in weight about three per cent. of the rock, is intimately mixed with the powdered rock, and the mixture is deposited in a hopper above the furnace shaft.

The draft and gas flames having been started, the comminuted mixture of rock and carbon is continuously fed into the holes at the top of the shaft, passing int othe furnace with the flames and air. The particles of carbon and of copper mineral are immediately ignited and oxidized by the oxygen of the air in which the particles are suspended and diffused.

This oxidation is combustion, and produces an intense heat.

At first the carbon particles have their surfaces oxidized to produce carbon dioxide; but as the particles pass further down the shaft the oxygen of the air supply becomes exhausted, and then the carbon dioxide parts with half of its oxygen to the unburned incandescent carbon to form carbon monoxide, which last, in its turn, acts upon the oxides of copper and silver, taking their oxygen, thus reducing them to the metallic state.

As the heat is intense, these particles of metal are melted and assume globular shape.

The gold particles are likewise fused. The heat does not fuse the silica nor the lime. The result of this operation is a sand carrying in it minute globular particles of copper, gold and silver.

The dust and condensible gases are collected on the wetted surfaces of coke or stones in the condensing chamber and washed by the water to the bottom, where the water also meets the sand and carries it out of the furnace, in a constant stream upon concentrators, which separate the sand from the metal particles.

The metallic concentrates are then dried, melted and cast into merchantable shapes; such as copper anodes, when there is enough gold and silver to pay for the expense of electrolytic refining and separation of the associated metals.

The process is a continuous one and automatic from start to finish. It is cheap; and under the economic conditions of the localities we have considered the cost does not exceed one dollar per ton on a scale of treatment of one hundred to two hundred tons per day of 24 hours.

The gas drawn from the furnace by the exhaust fan is a combustible one, consisting mainly of carbon monoxide and nitrogen, and may be used for heating purposes. The sulphur dioxide and carbon bisulphide, if any of the latter, are condensed in the chamber and pass off in the water.

The limits of this paper do not admit of entering into specific details of construction and operation.

The process is applicable in many case where older methods are not practicable.

PRODUCTION OF MICA IN 1904.

Although mica has been found in commercial sizes in about one-third of the States and Territories, it has been mined during the past year in North Carolina, New Hampshire, Colorado, New Mexico, California, Georgia, South Dakota and Utah, which are named in the order of their importance as mica producers

The total quantity of sheet or plate mica produced in this country during 1904, as computed by Dr. Joseph Hdye Pratt of the United States Geological Survey, was 668,358 pounds, valued at $109,462, an increase of 48,758 pounds in quantity but a decrease of $8,626 in value, as compared with a production of 619,600 pounds, valued at $118,088, in 1903. It appears that in 1903 and 1904 the production was nearly 300,000 pounds greater than in 1901 and 1902. This large increase in the production of sheet mica during the last two years is due to the very large quantity of the small-sized disks and rectangular sheets of mica that have been prepared for electrical purposes.

The production of scrap mica during 1904 amounted to 1,096 short tons, valued at $10,854, as against 695 short tons, valued at $6,460 in 1903. During 1903, however, there were also reported 964 short tons, valued at $18,580, which were sold in the rough blacks as produced. This probably made at least 800 tons of scrap mica, so that the actual production of scrap mica in 1903 was greater than that in 1904. Of the 1904 production, 610,121 pounds of sheet mica, valued at $100,724, and 200 short tons of scrap mica, valued at $2,000 were produced in North Carolina. This was over nine-tenths of the total production of the United States in 1904.

The imports of mica have, in late years, been several times greater than the home production. This is partly due to the fact that mica from Canada and India, which can be entered at a low valuation, has a tendency to curtail the production of mica in the United States. During 1904, 1,085,343 pounds of unmanufactured mica, valued at $241,051, and 61,986 pounds of cut or trimmed mica, valued at $22,663, were imported into the United States.

Many interesting details concerning the nature, occurrence and uses of mica were given by Doctor Pratt. This report, which is published as an extract from the Survey's forthcoming volume, "The Mineral Resources of the United States, 1904," is available on application to the Director of the United States Geological Survey, Washington, D. C. .

PURIFICATION OF WATER FROM ALGAL CONTAMINATION.

There is not a State in the Union which has not reported difficulty from algal growths in water, and in some communities the odor and taste during certain months of the year have rendered the water absolutely unfit for use. In a few cases the strong odor has even necessitated the giving up of the use of the water for sprinkling the streets and lawns. One water commission in New England considered the trouble due to algæ of so much importance that they were willing to expend about four million dollars

upon devices, and by means certainly effective, in order to try and prevent such difficulties. A city in the far West spent over one million dollars securing new sources of supply so that the algal-polluted reservoirs might be abandoned. In the South we have a case where the algæ led the local authorities to take steps to cause the franchise of the water company to be forfeited, on the ground that they were not furnishing a potable water. The company had spent thousands of dollars in mechanical filters and other devices, without results, and there was no alternative but to install a new supply at a cost of double the one already in use. It is needless to say that a question of so much financial importance has been investigated exhaustively from the so-called practical side, and various recommendations made, all of little or no effect. Finally, the difficulty was relegated to the botanists, who took hold of the problem from the purely scientific standpoint and showed how certain plants were the specific cause of the trouble. It was then a comparatively simple matter, by applying the knowledge gained years ago by Naegeli and others in botanical research, to find a remedy for the difficulty. The only wonder is that it was not thought of before. Within the last six months the method of destroying or preventing the growth of algæ in water supplies, as devised by the Department of Agriculture, has been used with marked success in over fifty water supplies throughout the country, on a scale running into the hundreds of millions of gallons, and causing a saving of money difficult to estimate.—*Scientific American Supplement.*

ACTIVITIES OF THE LAKE SHIPYARDS.

With sixteen vessels under order at Lake shipyards for delivery in 1906 practically all available berths are now taken a year ahead, a condition never existing before. With repairs, the lengthening of vessels and further orders pending for new vessels, full occupation for the lake yards seems now assured for eighteen months. The sixteen vessels, as above, added to those finished, or to be finished, this year, make a total of forty new boats, with a total ore carrying capacity on one trip of 360,500 tons. In a season, estimating twenty trips, they could carry 7,210,000 tons of ore. Such an unprecedented addition to the lake fleet suggests large expectations as to the increase in iron ore shipments in the next few years.—*Iron Age.*

CHINA'S THREATENED BOYCOTT.

The threatened boycott of American goods in China should be very easily remedied if the resolutions of the Shanghai Chamber of Commerce reflect the general Chinese position. It appears that there is no complaint of the exclusion of the Chinese laborer. The resolution of the Chamber of Commerce, addressed to the Board of Foreign Affairs of the Chinese Government, states: "We beg to inform you that the community are discontented with the present situation, and all those connected with this body have decided to cease all traffic in American goods until such time as a satisfactory settlement is arrived at. As this matter concerns all classes

throughout China we sincerely desire tnat you will instruct our Minister to withhold his signature until the right of entry into America is accorded all traders, students and gentry." If a system could be developed so that the classes named might be given the right of entry without making possible the wholesale migration of Chinese, probably no one would object. America does not wish to see her goods boycotted at a time when the keenest efforts are being made by Europe to get more than its share of the Chinese trade, the tremendous future possibilities of which are being better and better understood.—*Iron Age.*

COAL PRODUCTION.

Reports to the United States Geological Survey for 1904, as collected by Mr. Edward W. Parker, statistician, show that the production of coal last year amounted to 351,196,953 short tons, having a total value at the mines of $445,643,528. Compared with 1903 this shows a falling off of 6,158,463 short tons in quantity, and of $58,080,853 in value. This decrease, although proportionately large in the figures of value, does not indicate any interruption to the generally prosperous conditions which have prevailed during the last eight years. It was simply a natural reaction from the abnormal activity which had been maintained throughout the coal mining regions in 1903, due to the exhaustion of all coal stocks on hand by the memorable strike of 1902. In order to renew the coal stocks and at the same time to provide fuel for immediate use, the coal mines in 1903 were pushed to their utmost capacity, or, one should probably say, to the capacity of the railroads to handle the output. As a result the enormous production of 357,356,416 short tons was recorded. Prices raised high by the famine of 1902 remained high for a large part of the year, and the total value of coal at the mines, before any expense of transportation or selling costs had been added, amounted to $503,724,381, an increase of $136,600,000 over that of 1902. The production in 1904, while less than that of 1903 by 6,159,463 short tons, exhibits a normal increase when compared with the annual production during the ten preceding years. The average price for all coal mined and sold in 1904 was $1.27, as compared with $1.41 in 1903, and $1.22 in 1902. Some day it will be interesting to have brought out the effect of water power development, etc., in reducing coal production.

The Corporation of the Massachusetts Institute of Technology has voted in favor of the proposed alliance with Harvard University. The faculty and alumni of the institute were in a large majority opposed to this union, but the action of the corporation is presumed to be final. The identity of the institute will be retained, and it will have the income of the various funds which now support the Lawrence Scientific School, as well as the income of the large McKay endowment. The alliance as proposed contemplates the erection of a new home for the institute on the Charles River, at a point about opposite Harvard University in Cambridge.

Book Notices.

Traité Theoretique et Pratique d'Electricité. Par H. Pecheux, Professeur de physique et de chimie á l'Ecole Nationale d'Arts et Métiers d'Aix. Avec notes additionneles de J. Blondin et E. Néculcea. Preface de J. Violle, membre de l'Institut. Un volume in 8 de 720 pages, 800 illustrations. (Broché, 17 fr.; relié, 20 fr.) Paris; Librarie Ch. Delagrave, 15 rue Soufflot. 1904.

This work constitutes an exhaustive treatise on theoretical and applied electricity, designed especially for the use of advanced students of the national technical schools of France. It is profusely illustrated, and has apparently been brought well up-to-date. It may be used to advantage as a reference work by all electrical engineers and advanced students of the science. W.

The Urine and the Clinical Chemistry of the Gastric Contents, the Common Poisons and Milk. By J. W. Holland, M.D., Professor of Medical Chemistry and Toxicology in Jefferson Medical College of Philadelphia. Seventh Edition, revised and enlarged, with 71 illustrations. 172 pages Note Book 12 mo. P. Blakiston's Son & Co. $1.00.

This laboratory manual has been so long before the public that, as the numerous editions show, its merits are evident. It is a comprehensive and compact statement of the data in regard to the topics noted in the title, and is printed so as to be available as a notebook. It is liberally illustrated and neatly printed.

The centrifugal process for determining fat, given on pages 169-170 is a slight modification of a well-known process, and it would have been more commendable if Dr. Holland had given credit to the originators of the fundamental process. In most other statements of the book the name of the originator of any process is given and the omission in this case seems strange. H. L.

Reform der Unkostenberechnung in Fabrikbetrieben. Von A. Sperlich. Verlagsbuchhandlung von Gebrueder Jaenecke, Hannover. Preis, Marks 5.

In the above work the primitive methods of accounting formerly used by the masters of small shops, who had only to add their "Master's Pence" to the actual cost of wages and material, in order to arrive at the proper charge for their productions, is compared with the book-keeping and accounting systems now used in large modern manufacturing establishments, where the necessity for expensive machinery, power for driving same, electric light plants, steam heat, railway sidings, Government regulations for sanitation and comfort of workmen, a large staff of managers, book-keepers, clerks, draftsmen, foremen, etc., render the calculations for a proper selling price a complicated and difficult matter, etc., etc.

While under the ancient system an addition of about 10 per cent. to the actual cost of wages and material would be ample to cover general expenses and secure a proper profit, the modern system would require an addition of 100 per cent. to the same basis, depending mainly on the proportion of men and machinery employed.

Three different branches of manufacture have been chosen by the author to illustrate the principles which he wishes to elaborate, the production of the different articles is followed through all its stages, and in each one the proper proportion of expense to cost of labor and material is worked out in detail.

In these days of sharp competition and constant development of new systems, new machinery, etc., it is certainly of the highest importance to the manufacturer to make the most exact calculation of the cost of his productions, to enable him to compete with others, while at the same time securing a legitimate profit, and this work will give him valuable hints in this direction. J. H.

PUBLICATIONS RECEIVED.

Souvenirs Entomologiques. (Etudes sur l'instinct et les mœurs des insectes), par J.-Henri Fabre, correspondent de l'Institut, 9 volumes. Tome IX. — 1 vol. in-8°, avec illustrations, br. 3 fr. 50. From the publisher, Ch. Delagrave, Paris, France.

Jahrbuch für das Eisenhüttenwesen. (Ergänzung zu „Stahl und Eisen".) Ein Bericht über die Fortschritte auf allen Gebieten des Eisenhüttenwesens im Jahre 1902. Im Auftrage des Vereins deutscher Eisenhüttenleute bearbeitet von Otto Vogel. III. Jahrgang. From the publisher, A. Bagel. Daseldorf. 1905. (Price, 10 marks.)

Thermodynamik technischer Gasreaktionen. Sieben Vorlesungen. Von Dr. F. Haber. 8 vo. xvi 296 Seiten. Mit 19 Abbildungen. Muenchen und Berlin. Verlagsbuchhandlurg R. Oldenbourg. (Price, 10 Marks.) From the publisher.

The Pennsylvania State College Catalogue 1904-1905. Fiftieth year. State College, 1905. 324 pages, 12mo.

Annual Report of the City Engineer of the City of Providence for the year 1904. Providence, City Printers, 1905. 81 pages, plates, maps, tables.

Report of the Commissioner of Education for the year 1903, volume 2. Washington, Government printing office, 1905. 1217-2511 pages, 8vo.

Project of Terminal Harbors for the Panama Canal, by Lindon W. Bates, with general plans and sections showing proposed canal terminals, town sites, locks, barrages, outer and inner harbors and naval stations, Panama and Limon bays. New York, author, 1905. 27 pages, plates, maps, Quarto.

Experiments with the Langley Aerodrome, by S. P. Langley. From the Smithsonian Report for 1904, pages 113 to 125 (with one plate.) Washington, Government printing office, 1905.

Fifth Annual Report of the Mining Bureau to the Honorable Secretary of the Interior, by H. D. McCaskey, chief of the mining bureau for the year ending August 31, 1904. Manila, Bureau of public printing, 1905. 44p. illustrations, plates, maps, 8vo.

North Carolina Geological Survey, Bulletin No. 19. The tin deposits of the Carolinas by Joseph Hyde Pratt and Douglass B. Sterrett. Raleigh, Public printers. 1904. 64 pages, illustrations, maps, 8vo.

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THE FRANKLIN INSTITUTE

Stated Meeting, held Wednesday, April 19, 1905.

The Improvement of the Delaware River and Harbor and the Landing Facilities of the Port of Philadelphia.

BY GEORGE S. WEBSTER, Member of the Institute.
Chief Engineer Bureau of Surveys, Dept. of Public Works, Philadelphia.

[A description of the work done by the City of Philadelphia, in conjunction with the United States Government in the improvement of the channels of the Delaware and Schuylkill Rivers, and the improvement of the landing facilities of the port, by the widening of Delaware Avenue and the construction of larger and more commodious piers.—THE EDITOR.]

This subject may best be considered under two headings: (1) The Improvement of the River Channel, which was begun by the United States Government, and supplemented by appropriation for the State of Pennsylvania and the City of Philadelphia; and (2) the Landing Facilities of the Port, which are being carried out by the City and the owners of the wharf property.

HARBOR IMPROVEMENTS.

The project as approved by the United States Board of En-

gineers for improving what is known as the Harbor of Philadelphia, which extends in front of the city from Fisher's Point to Kaighn's Point, a distance of five and a-half miles, involved the removal of Smith's and Windmill Islands, covering about twenty-five acres, a portion of Petty Island of forty acres, and the formation of a dredged channel of a width of 1900 feet between pierhead lines, of a least depth of 26 feet at mean low water for 1000 feet in width along the Philadelphia front, and for the remaining 900 feet of width, of a depth decreasing from 26 feet to 12 feet at low water along the Camden side.

On August 11, 1888, Congress appropriated $500,000.00 to inaugurate the work. The Act provided that the title to Smith and Windmill Islands and that portion of Petty Island taken be first acquired by the United States, but limited the amount to be expended for that purpose to $300,000.00. The State of Pennsylvania, by Act of May 31st, 1889, appropriated $200,000.00 and the City of Philadelphia, by ordinance of May 15th, the same year, appropriated $230,000.00 to aid in securing the title to the Government, and the City actually paid of this sum, $208,652.86. The harbor work was begun in 1891, but very little was accomplished until 1893, the work in the harbor under the project being completed in 1897.

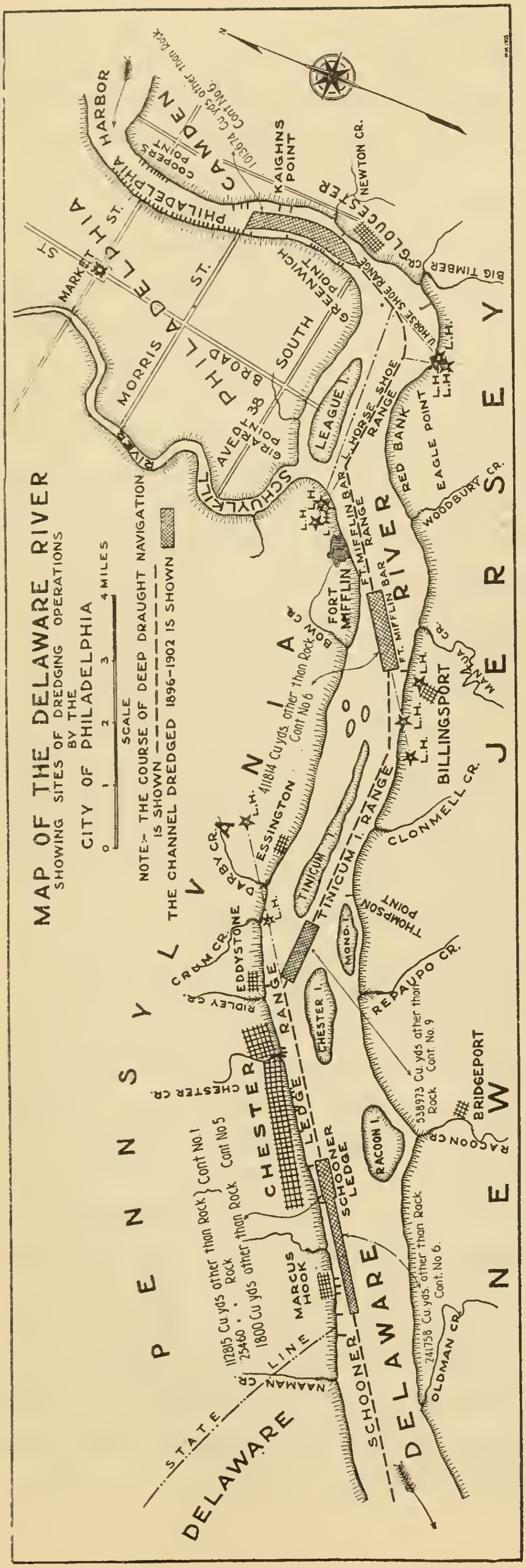
DELAWARE RIVER IMPROVEMENT.

The project under which the work of improving the Delaware River from the harbor to the sea was being carried on was adopted by the United States Government early in 1885, and provided for the formation of a channel 600 feet wide and 26 feet deep at mean low water.

Owing to the inadequacy of the Government appropriation and in response to the demands of commerce, together with the urgency for obtaining at once a channel 600 feet wide, and 26 feet deep, from the City to deep water in the Bay, to better enable the City of Philadelphia to compete with the other large shipping ports on the Atlantic Coast, Councils, on December 28th, 1894, appropriated $225,000.00 to supplement the work of the United States Government in the removal of shoal places and other impediments, interfering with the navigation of large vessels to and from the Port of Philadelphia.

Additional appropriations were made by the City in the years 1895, 1896, 1897, 1898, 1899, and 1902, aggregating $1,555,000.00, of which $770,000.00 was expended in improving the channel of the Delaware River, the remaining amount being applied to deepening the channel of the Schuylkill River.

The work undertaken by the City was in accordance with the adopted project of the United States Government, and was under the general supervision of the Engineer Officer in charge of the River Improvement. That in the channel of the Delaware River comprised (1) the removal of a portion of Schooner Ledge Rock and the deepening of the channel along that range. The ledge is situated in the line of the Schooner Ledge Lighthouse range, opposite and immediately south of the Steel Works Wharf at South Chester. It resulted in the removal of a dangerous obstruction to navigation, and the formation of a channel 600 feet in width and not less than 26 feet in depth at mean low water, through the ledge of rock at that locality. Also the removal of that portion of Illinois Rock adjacent to Schooner Ledge, which projected into the channel; (2) The removal of the bar or middle ground at Greenwich Point and the deepening of the western channel of the Delaware River along the front of the City of Philadelphia from the prolongation of the lines of Avenue 38 south to the prolongation of the lines of Morris Street, the lower limit of the improvement of the harbor. This work was practically an extension southward of the Philadelphia Harbor, and was prosecuted within channel boundaries ranging from 950 to 1050 feet apart, resulting in the formation of an additional length to the channel, and to the anchorage grounds of the harbor of 10,000 lineal feet; (3) the deepening of the channel through Fort Mifflin Bar, about midway between Fort Mifflin and Lincoln Park Wharf, immediately in the line of the Fort Mifflin Bar Lighthouse range. It also included the removal of the shoal at the south end of Tinicum Island. The work performed by the City resulted in securing a channel of a least width of 600 feet and 26 feet deep at mean low water from the southern end of the Philadelphia Harbor at Kaighn's Point, through the middle grounds of Greenwich Point, the Fort Mifflin Bar, Tinicum Island shoal and Schooner ledge to near the southern boundary of the State, a distance of about eighteen miles.



On September 20th. 1899, in accordance with a report of the Board of Engineers, the Secretary of War approved the present project for improving the Delaware River, by creating a channel 600 feet wide and 30 feet deep from Christian Street to deep water in the Delaware Bay.

In this report no dikes were recommended for the maintenance of the channel, but the formation of an island to be made of the material excavated was authorized opposite Reedy Island.

The Government has been at work on this project ever since its approval, and work has advanced from the Delaware Bay northward as rapidly as the available funds would warrant, the portion from the Bay to Fort Delaware, a distance of twenty-one miles, being completed.

Owing to the increase in the size and draught of modern ocean steamers a demand has arisen in the Commercial, Maritime and Trade Organizations of this city for the adoption of a project for a channel 35 feet deep at mean low water, and at

the last Congress a resolution was passed by the Senate directing the Secretary of War to report to the Senate, as early as practicable, an estimate of the cost of deepening the channel of the Delaware River, Pennsylvania, from Allegheny Avenue, Philadelphia, to deep water in Delaware Bay, to 35 feet.

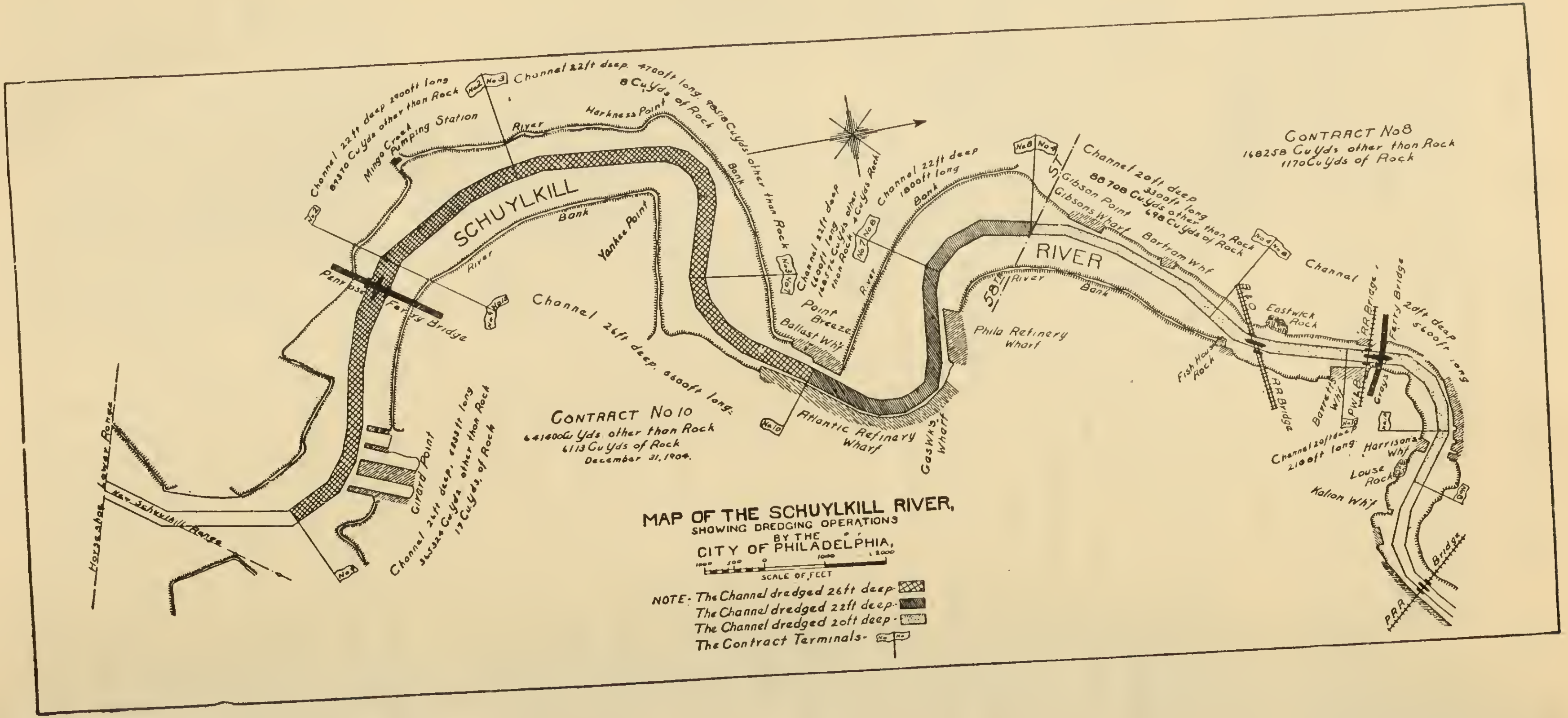
SCHUYLKILL RIVER IMPROVEMENT.

The United States Government in recent years has not appropriated funds for the improvement of the channel of the Schuylkill River, it being the policy of the Committee on Rivers and Harbors not to grant any funds to rivers located entirely within municipalities, so this work has fallen upon the City of Philadelphia. The magnitude and importance of the commerce of this river demands that facilities for deep-draught vessels be given, to accommodate the great shipping interests located at Girard Point and Point Breeze, a large percentage of the whole foreign export trade of the Port of Philadelphia going out of this river.

The work undertaken by the city in the Schuylkill River has resulted in a channel 26 feet deep at mean low water and 250 feet to 300 feet wide from the mouth to Point Breeze Harbor, and from this point 250 feet wide and 22 feet deep to Gibson's Point, and thence 150 feet wide and 20 feet deep to a point 500 feet beyond Harrison's Wharf, north of Gray's Ferry Bridge, a total distance of about six miles. The controlling depth in this portion of the river prior to the commencement of work by the city was about 18 feet at mean low water.

DISPOSITION OF DREDGED MATERIAL.

In accordance with the provisions of the Ordinance of Councils, approved April 2d, 1898, the material dredged by the City of Philadelphia from the Delaware and Schuylkill Rivers, with the exception of the rock from Schooner Ledge, was deposited on low ground adjacent to the rivers, within the city limits. A great part of it was placed upon League Island Park, a tract of 300 acres of low land acquired by the city for park purposes at the southern end of Broad Street, adjacent to League Island Navy Yards. A portion of rocky material removed from Schooner Ledge was dumped in front of the city as a support to



MAP OF THE SCHUYLKILL RIVER,
SHOWING DREDGING OPERATIONS
BY THE
CITY OF PHILADELPHIA.

the piles of the bulkheads and new piers constructed along Delaware Avenue. The remaining rock was deposited back of Chester Island in such a location as not to interfere with navigation.

RECENT LEGISLATION.

The Pennsylvania State Legislature recently passed an appropriation of $375,000.00 to expedite the work of improving the channel of the Delaware River between the City and the Bay, conditioned upon the City of Philadelphia making a like appropriation. This bill is now in the hands of the Governor for his approval, the work to be done by the Bureau of Surveys, Department of Public Works, of this city, and in accordance with the adopted project of the United States Government.

LEADING FACILITIES OF THE PORT.

As the work of increasing the depth of the channel of the river was progressing, preparations were made for increasing the landing facilities of the port. The necessity of wharves of sufficient length to dock large vessels was recognized and a revised wharf line increasing the limit to which piers may be extended in the Delaware River was established by ordinance approved October 7th, 1891.

In accordance with the ordinance and the project of the United States Engineers for the improvement of the harbor of Philadelphia the bulkheads and wharf lines were so established as to admit of the widening of Delaware Avenue and the extension of the piers along the river front so as to obtain lengths from 500 feet to 650 feet.

HISTORY OF DELAWARE AVENUE.

Upon the original plan or map of the City of Philadelphia, made by Thomas Holme, in 1682, the present Front Street corresponded with the west bank of the Delaware River. Lots were sold fronting on the westerly side of Front Street, the easterly side remaining as a bank or open common.

Between the years 1684 and 1690 the demands of commerce and the occupancy of certain portions of the river bank by stores caused a change in policy, as patents for bank lots lying

eastward of Front Street were issued to citizens prior to and during 1690-1691.

These patents restricted the heights of buildings on the bank side of Front Street, which gave rise to a petition from the owners to build as "high as they pleased." After consideration the Commissioners of the Proprietary formulated what is known as the "Regulation of the Bank." The petition was granted, one of the conditions being that all owners "shall regularly leave thirty foot of ground in the clear, for a cartway and along the said whole bank, and in convenient time shall make the same to be a common and public cartway for all persons, by day and by night, forever hereafter." This indicates the way in which Water Street was first laid out.

Commerce during the time of Stephen Girard had so increased, and with it the extension of wharves further into the river and the building of stores near the wharves, as to demand further encroachments upon the river. A firm belief in the future commercial importance of Philadelphia and a keen grasp of the necessities of the time and of the future, undoubtedly were possessed by Stephen Girard, to enable him to plan as he did, not only for laying out a new front street (Delaware Avenue) on the Delaware River, but to plan and provide for its expansion, as indicated by the following section of his will, proved December 31st, 1831, in which he set aside $500,000.00, the interest to be used as follows:

"To lay out, regulate, curb, light, and pave a passage or street on the east part of the City of Philadelphia, fronting the River Delaware, not less than twenty-one feet wide, and to be called Delaware Avenue, extending from Vine to Cedar Streets, all along the east part of Water Street squares, and the west side of the logs which form the heads of the docks, or thereabouts; and to this intent to obtain such Acts of Assembly, and to make such purchases or agreements, as will enable the Mayor, Aldermen, and Citizens of Philadelphia to remove or pull down all the buildings, fences, and obstructions which may be in the way, and to prohibit all buildings, fences or erections of any kind to the eastward of said Avenue; to fill up the heads of such of the docks as may not afford sufficient room for the said street; to compel the owners of wharves to keep them clean and covered completely with gravel or other hard

Jour. Franklin Inst. Vol. CLX., Sept. 1905.

Smith and Windmill Islands, now removed.

Setting foundation blocks for bulkhead.

materials, and to be so leveled that water will not remain thereon after a shower of rain; to completely clean and keep clean all the docks within the limit of the City fronting on the Delaware; and to pull down all platforms carried out from the east part of the City over the River Delaware, on piles or pillars."

By Act of Assembly of March 24th, 1832, the Mayor, Aldermen and Citizens of Philadelphia were authorized to carry into effect certain improvements and execute the trusts under the will of Stephen Girard.

Delaware Avenue was first laid out twenty-five feet wide from Vine to Cedar (South) Streets under authority of an Ordinance of Councils, approved February 27th, 1834, and by various ordinances covering a period from 1834 to 1839, the opening of portions of this Avenue were authorized. Proceeding under authority of the Act above quoted, the Trustees under the will of Stephen Girard performed and bore the expense of this work, covering a period from 1834 to 1845.

The growth of commerce at this time demanded further increase in the facilities, and the Trustees, acting under the same authority, between the years 1857 and 1867, widened the Avenue from twenty-five to fifty feet between Vine and South Streets.

That portion of the Avenue between Dock Street and Washington Avenue was placed upon the City Plan of the width of eighty feet by Act of Assembly of May 15th, 1871, and Ordinance of Councils of May 13th, 1872.

Upon the establishment of the new bulkhead line admitting of the recent widening of Delaware Avenue, Councils by ordinance of June 23d, 1893, authorized the placing of the Avenue upon the City Plan between Christian Street and Laurel Street to a least width of 150 feet, the easternmost line to conform to the bulkhead line established by the Secretary of War. Plans were prepared in accordance with the ordinance, the increased width of the street being taken from the docks on the easterly side of the Avenue, except at Pine and Lombard Streets, where corners of buildings on the westerly side were cut off, and between Market and Walnut Streets, where the westerly line of the Avenue as laid down cuts off several feet from the

Concrete bulkhead

fronts of properties. This plan was confirmed by the Board of Surveyors November 19th, 1894.

By Ordinance of March 11th, 1895, Councils authorized the physical widening of the Avenue between Vine and South Streets, except the properties on the west side between Market and Walnut Streets, and empowered the Mayor of the City to negotiate with the property owners with a view of adjustment of the damages by reason of the taking of the property for the widening.

These negotiations resulted in a majority of the owners agreeing amicably with the city upon the amount of damages suffered, which were finally adjusted without litigation, with the exception of four owners on the east side of the Avenue, and a few owners on the westerly side, whose interests were such that the basis upon which negotiations were made could not be accepted, but for which adjustments were finally made on a different basis.

As a result with the settlements with these latter owners the City acquired 363 feet $5\frac{1}{8}$ inches of additional water front property, and coincident with other corporations and individuals at once proceeded to tear down old buildings and build new and enlarged structures, some of them of steel, giving additional accommodations to shippers and inviting commerce to the port.

The City of Philadelphia owns valuable water-front property, between Vine and South Streets, including piers at the foot of Race, Arch, Chestnut and Dock Streets, also north of Race Street, and other property at the foot of Vine Street, Market and South Streets, being used by ferry companies under leases.

AUTHORIZATION OF WORK.

On January 13th, 1896, a loan was created of $1,500,000.00 for the purpose of carrying on the improvement of Delaware Avenue, and the work of widening, constructing bulkheads, building of sewers, and extension of the City piers was authorized by Ordinance of March 31st, 1896.

By Ordinance of November 27th, 1896, the Board of Directors of City Trusts was authorized to join with the City of Philadelphia in carrying on this work, and agreed to set aside the sum of $650,000.00 for this purpose, which represented the sur-

Delaware Avenue after Completion of Improvement.

plus interest which had accumulated from the original bequest of $500,000.00 by Stephen Girard.

The necessary legislation having been enacted measures were taken to begin the construction of the work. The first essential was the building of a bulkhead about 5200 feet in length and the reconstruction of about 8000 lineal feet of sewers of various sizes in the streets adjacent, on a system by which the ordinary flow of the sewage was intercepted and carried out to discharge at the pierhead line, while the storm water was permitted to discharge at the heads of the docks. The work also included the filling-in of the reclaimed areas and the paving of the entire Avenue.

BULKHEAD WALL.

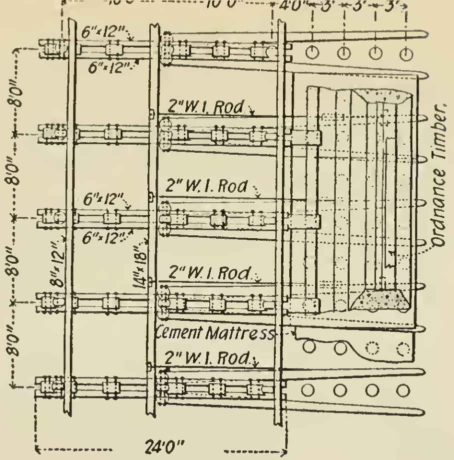
The reclaiming of a strip of from 70 to 100 feet in width, taken from the docks, having a depth of water varying from four to twenty feet, covering a layer of soft mud from ten to forty feet thick, resting on the gravel bed of the river presented a number of problems for solution: (1) The best method of dealing with this soft river bottom to insure stability in the completed structure; (2) the best way to confine the filling to prevent movement in the bulkhead; and (3) the best type of bulkhead to adopt to meet the requirements of stability, economy and appearance.

The plan adopted was for a concrete wall resting on piles sawed off twelve feet below mean low water, excepting short sections back of the piers and ferries, which consisted of a concrete wall upon timber platform.

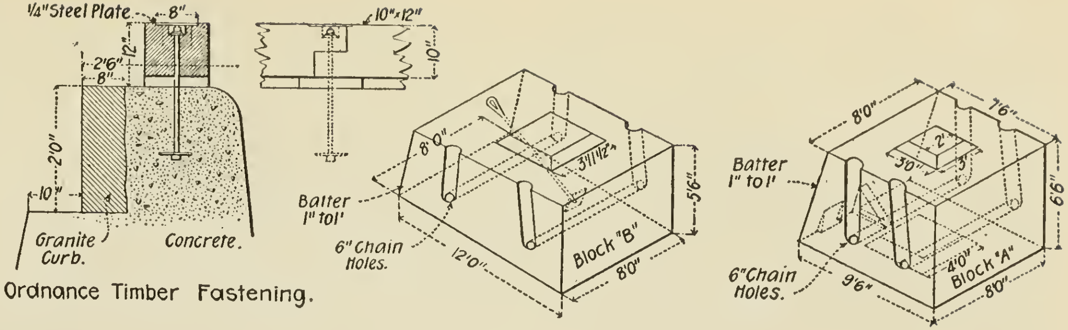
The consistency of the mud filling in the docks was such that it was essential to dredge it out and deposit coarse gravel or broken rock as a support for the piles, which were then driven and sawed off about twelve feet below mean low tide.

Upon these piles a foundation for the concrete wall, consisting of two courses of large concrete blocks, weighing thirty-two tons each, were placed, the upper block being visible at low water. Upon these blocks forms were erected and the balance of the concrete wall built in place.

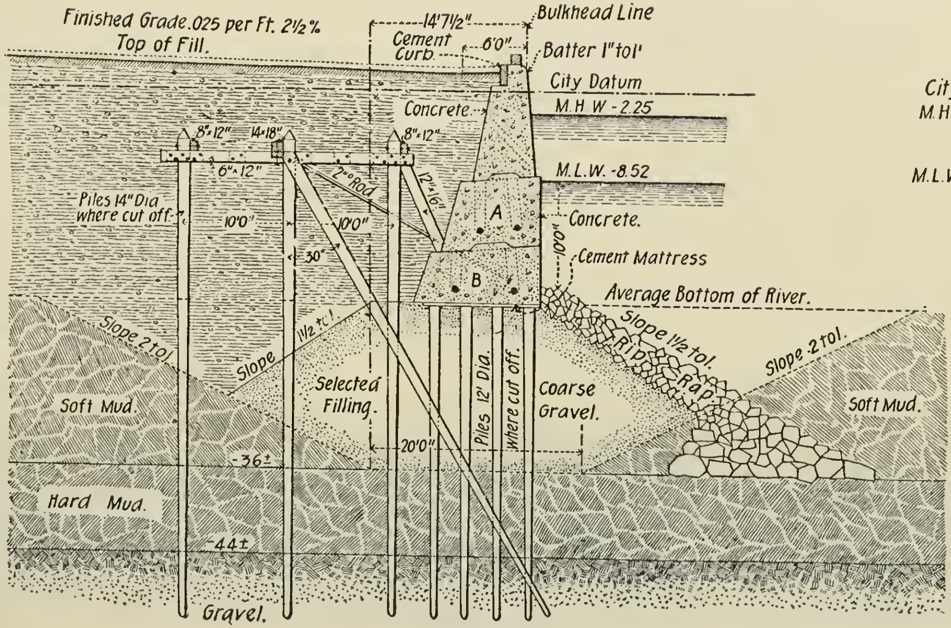
The system adopted for intercepting the sewage did away with a nuisance which was for a long time the source of com-



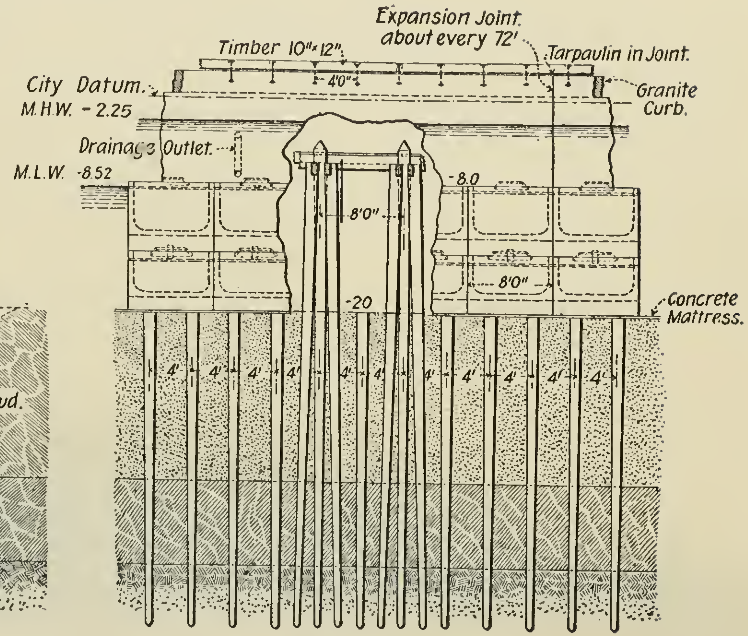
Plan.



Ordnance Timber Fastening.



Cross-Section.



Front Elevation.

THE ENGINEERING RECORD.

plaint from the pier owners and from the traveling public using the ferries.

CONSTRUCTION OF PIERS.

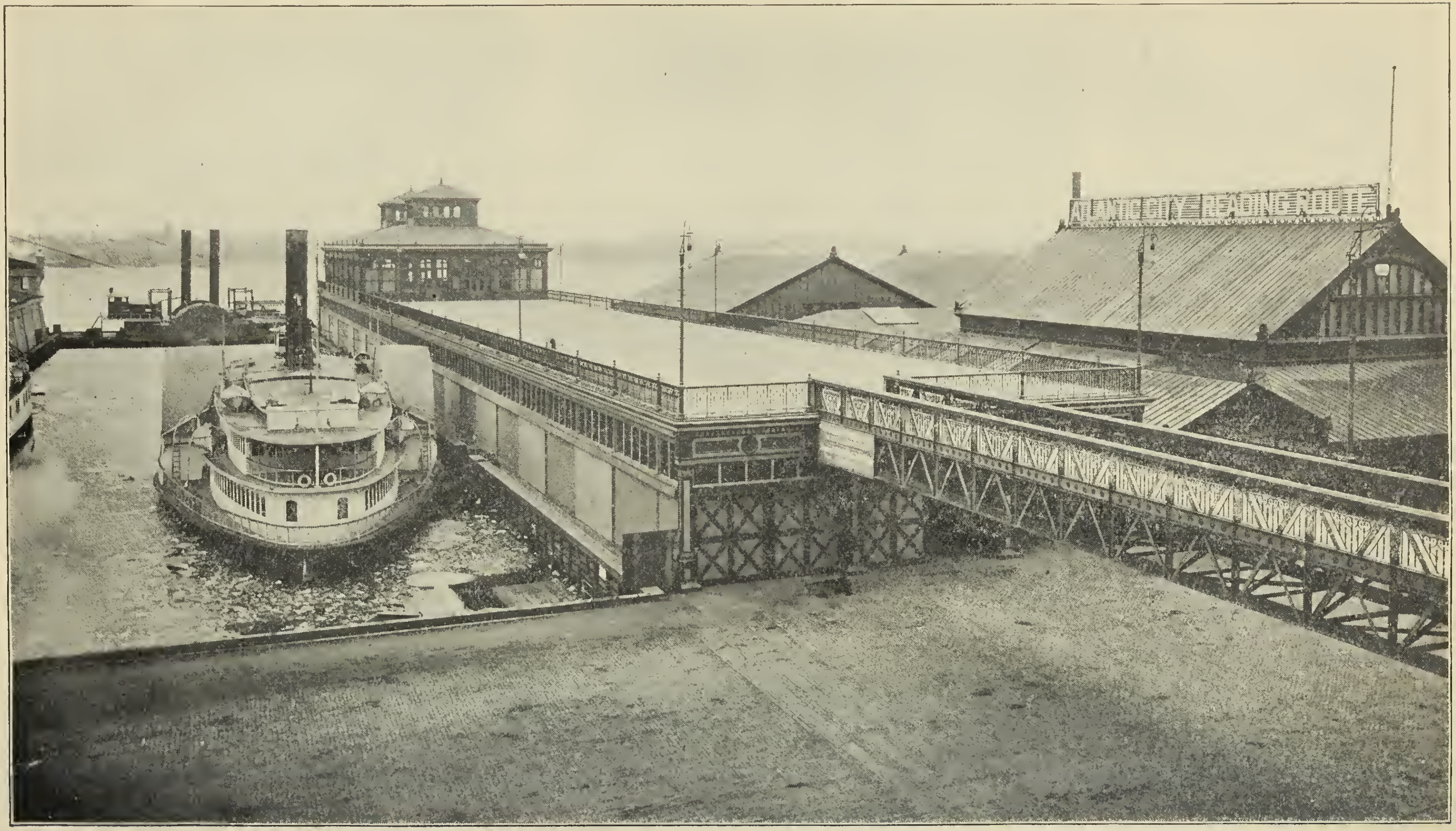
In connection with the work of widening Delaware Avenue the city reconstructed and extended the piers upon its own property at Race, Arch and Chestnut Streets, the general dimensions of the three being 80 feet in width, by lengths varying from 530 to 540 feet.

The City also leased property north of Race Street to the Baltimore & Ohio Railroad Company on an improvement lease, under the condition it should construct a pier 60 feet by 540 feet and turn the same over to the City in good condition at the termination of its ten years' lease.

The substructures of the piers constructed by the City and most of those by individuals were open pile foundations. In order to provide a footing for the piles, coarse gravel or broken stone was dumped on the site of the piers to a height of thirty feet below low water, and the piles afterwards driven.

The piers at Chestnut Street and Race Street were considered suitable places for providing pavilions for the accommodation of the public, to be used for recreation purposes. To this end more elaborate structures were designed at these locations, comprising, in addition to the freight facilities on the lower decks, upper decks and covered pavilions.

The results obtained from the improvement of the channel of the Delaware River and the landing facilities of the port, to those who will recall the dilapidated condition of the sheds and stumps of piers, which existed prior to the commencement of the work, are fully apparent. From a narrow avenue fifty feet in width, with numerous ruts in the paving, upon which, during the hours of business, there were several lines of drays badly blocked at times, and forming a barrier to pedestrians to and from the ferries and piers, there is now a broad avenue, permitting of the speedy removal and delivery of freight. Piers have been constructed and freight stations have been greatly enlarged and new and commodious buildings of a permanent character upon the east line of the Avenue have been built. The rapidity of the growth of these improvements has exceeded all expectations.



Recreation pier at Chestnut Street.

Negotiations have been completed with the owners of property between Vine and Green Streets with a view of carrying the improvement to the northward. This work now awaits authorization from Councils.

The completion of the paving upon a concrete base had been delayed for several years, until by agreement the three steam railroads having rights upon the Avenue acceded to the demands of the city officials, fixing upon three tracks as the maximum number to be allowed.

Thereafter the Girard Estate placed the paving under contract, setting aside additional funds for the purpose, and completed it late in the year 1904.

The total expenditure by the City and the Girard Estate in widening Delaware Avenue and constructing the piers and otherwise improving the facilities of the port was $2,247,361.05, of which amount the Girard Estate expended $779,933.03 and the City $1,467,428.02. $999,856.70 of the City's expenditure was for acquiring the additional property and for paying damages for the widening of the avenue.

The Philadelphia Rapid Transit Company, lessee of the Frankford Elevated Passenger Railway Company, is authorized ,by ordinance, to construct an elevated railroad on Delaware Avenue, between Vine and South Streets, and plans are now being prepared for the portion south of Arch Street, with a connection to the Market Street Subway. This will greatly facilitate passenger travel, as convenient connections will be made with all the ferries, steamship and steamboat lines.

STEAM-TURBINE OPERATION.

According to *Power*, July, 1905, in two instances lately reported turbines having a multiplicity of blades have lost a large quota of them without coming very seriously to grief. In one case the turbine in a cotton mill was opened every night and as many of the blades put back as possible, the case put back and the machine put to work next day as though nothing were wanting. In another plant, it was noticed that it was necessary to cut more resistance than ordinary out of the field coils to keep up the voltage and the turbine was found to be running slow. Investigation showed that all, or nearly all, of the blades of the intermediate stage were in the bottom of the case. The turbine ran along in this condition until an opportunity afforded to put them back and without an appreciable difference in the cost of aperation.

(Webster)

Recreation pier at Race Street.

Electrically Welded Screw Caps and Bolts.

[*Being the Report of the Committee on Science and the Arts on the Method of the Cleveland Cap Screw Co. Sub-Committee, J. Logan Fitts, Chairman; D. Eppelsheimer, Jr., Arthur Falkenau, Chas. E. Ronaldson.*]

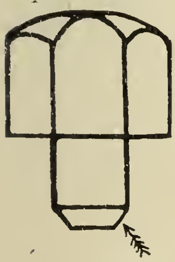
"Cleveland Cap Screw Co.'s Cap Screws and Bolts."

[No. 2312.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the merits of the "Cap Screws and Bolts," made by the Cleveland Cap Screw Co., of Cleveland, Ohio, reports as follows:

The cap screws made by the company named are intended to be used for the same purposes and in the same manner as cap screws have heretofore been used. The novelty of these screws is the method of their manufacture, in which the welding together of the head and body of the screw is done electrically, die-drawn stock being the material used, prepared for the purpose, and the heads are made to conform to the U. S. Standard, or Franklin Institute head. The following description is quoted from a letter from the manufacturers.

"For the heads we use specially die-drawn stock, hexagon, square or round, according to style of head required. This stock is drawn very accurately, with a variation not exceeding .003. The heads are cut from the bar on automatic machines, which turn a projection or shoulder to the diameter of the screw to be welded, as shown in the accompanying sketch.



The heads and stems are placed in the moulding machine and held firmly by copper vises, which are clamped to gun metal platens of large section, and to which are connected the terminals of the secondary circuit of the welder, which are moved on steel ways by hydraulic pressure. The sections to be welded are then brought together, thus completing the secondary circuit; the primary circuit being completed through a break-

switch, operated by a foot lever. The current is allowed to pass through these sections until they are brought up to a welding heat, then released at the same time the pressure is applied, forcing the two together, expelling any possible slag, or deteriorated metal, and forcing up a burr.

"The next process is the milling down of the burr, which is done by machinery especially constructed for this purpose. At the same time, the top of the head is shaved and trimmed, the under part of the head is forced and the end pointed. It will be seen that by this process we get absolute uniformity in the length of the screw, height of the head, and in the alignment of the head and body.

"The blank is then ready for threading. Here again we have special machinery, in which we employ lead screws for the purpose of taking all strains off the dies except those incident to removing the necessary material in forming the threads, which guarantees accurate threads.

As we cut the threads on the surface of the die-drawn stock and not the center, we have found by actual tests made for us that they have a much greater tensile strength than the milled or upset screws. With the milled screw, the thread is cut on the core of the material, which is conceded to be much weaker than the surface material, and with the forged-head screw an inferior grade of material is used. The fact that we use a special quality ot stock enables us to give our screws a very fine finish."

Quoting again another letter: "We call attention to our new process, case-hardened or Harveyized head cap screws, with soft die-drawn steel body, thereby avoiding all danger of threads being chipped or broken off.

"Also to our electric-welded brass head to steel body cap screw, which we are making in large quantities for switch-board and other electrical machinery manufacturers.

"We manufacture screws in all diameters up to and including 2″ diameter by any length."

The following is quoted from a report made by Mr. Eppelsheimer, who visited the works:

"This transformer is built into the base of the machine, forming a part of it, and has supplied to it an alternating current of 300 volts, with current necessary, which, for $\frac{3}{4}$″ bolts, is

about 97 amperes; and this is reduced to 2 volts and corresponding amperes, *i, e.*, about 14,500.

"As the two abutting surfaces are brought to the necessary heat the current is thrown on and off, by a foot treadle operating the primary circuit, allowing the heat to become uniform over the section, and then when the proper heat is obtained the whole is forced together with a horizontal movement of the jaws holding the head, with a pressure of from two and a-half to six tons, in some cases by hand-power through the medium of gears or by direct hydraulic pressure.

"The placing of brass heads on steel-bodied bolts or any other combination of metals is quite as easily accomplished, only on account of the difference in electrical conductivity the heads are made thus (arrow shows where the weld is to be, metal is champfered off or cut away) and this probably accounts for the serrated appearance of shavings taken from the weld of such bolts."

The Committee has examined the samples sent, and has had a few special pieces made for test. The welding of heads to bolt bodies is not new, but cap screws made with electrically-welded heads, within the knowledge of the Committee, is new.

The pieces mentioned as made from test were tested on an Olsen machine by pulling the heads off, resulting as the average of the five pieces, as follows:

The pieces were $\frac{3}{4}''$ screw bodies, with U.S.S. Hex, heads, bodies 8″ long—no threads. Average diameter .7485″—elastic limit 29920 pds. Ultimate strength 37900 pds. Elongation in 2″, .23″ (varying from .1 to .36″). Elastic limit per sq. in. 69000 pds., and about 86000 pds. ultimate strength per sq. in. The full table is appended. Eighty per cent. of the pieces gave way at the weld, with granular fractures; piece No. 3 giving way below the weld, in the body of the bolt, showing a true fracture of silky character. The welding appears to effect an annealing of the metal, as the elongation occurred within a small space at and near the weld on each piece.

Several samples of $\frac{3}{4}''$ body and about 6″ long, with a head welded on each end, were tested for torsion at the laboratory of the University of Pennsylvania by Prof. Spangler and your chairman, and the conclusion reached was, that at the welds, or near them, was the weakest point (not considering the

bottom of threads of finished bolts) but that these points compare favorably with the tensile tests showing 80,000 lbs. per sq. in., average angle about 90°.

The Cleveland Cap Screw Co. have furnished us with a copy of a report of tests made by the Wellman, Seaver, Morgan Co., and as we understand these tests were made with threaded bolts and none gave way at the welds, in this report a much higher tensile strength as the average of all sizes of screws is given, viz.: 97862 pds. per sq. in.

In order to determine the structure of the welds, an all-steel bolt was cut longitudinally through the head and body to a point below the weld, then carefully polished and etched with acid solution. The surface showed a fibrous arrangement of the particles of the metal, and at the weld a line of about ″ wide of quite a different character with no fibre markings,$\frac{1}{16}$ but each side of this the lines of the fibre curved outward as would naturally occur in forcing them together when hot. Test piece No. 5, after pulling head off, treated the same manner, and showed positive evidence of having broken at the weld.

A piece with brass head welded on was similarly treated showing the same fibre in the steel, but nothing marked in the brass. It was specially noted that a narrow line of copper color showed next to steel and that at the point of contact of brass and steel, the steel was eaten to a greater depth by the acid. From this it would appear that an electric couple is formed and a noticeably more rapid action occurred on the application of the acid.

The Committee find that here is a derth of information in the matter of physical tests of electrically-welded joints.

From "Electric Engineering Formula," page 673, Sir Frederick Bramwell found that $1\frac{1}{8}''$ round iron bars $14''$ long could be welded by the "Electric" process at the rate of $2\frac{1}{4}$ minutes per weld, giving a strength of 48000 pds. or 91.9% of the original bar, while by the ordinary blacksmith's method, 4 minutes were required per weld giving 89.8% of strength. In the former cases unskilled labor was used, while in the latter there were experienced smiths employd.

To show the adaptability of the electrically welding a number of metals, we quote further: "Prof. E. Thomson has a bar $\frac{3}{8}''$ diameter made by this process of nine different metals."

It is well understood that in screws milled from solid stock, the threads are cut on a body which is softer and weaker than the original outer surface and while a great economy in metal and a possible reduction in total cost is brought about by electrically-welding heads to bodies, the die-drawn stock itself is of much greater strength.

The following quoted from Kent's pocket book may be of interest in this matter:

"EFFECT OF COLD DRAWING ON STEEL."

1. Original bar 2.03″ diameter, 30″ long showed a T.S. of 55,400 lbs. Elongation of 23.9%.

2. Original bars reduced in compression dies (one pass) .094″ showed T. S. 70420 lbs. Elongation of 2.7% in twenty inches.

3. Original bar reduced .222″ showed T. S. 81,890 lbs. Elongation of .074% in twenty inches.

Tests of cold-rolled and cold-drawn steel made by the Cambria Iron Co. in 1897 (average of twelve tests):

	Elastic Limit.	T. S.	Elongation 8 In.	Reduction.
Before rolling.......	35,390	59,980	28.5 per cent.	58.5 per cent.
After cold rolling..	72530	79,830	9.6 "	34.9 "
After cold drawing..	76,350	86,860	8.9 "	34.2 "

In reference to the cap screws made with the U. S. Standard or Franklin Institute heads, we believe this to be an important item, practically as the small bearing shoulder, under an ordinary cap-screw head, which actually becomes less as the size of the screw increases, is very often crushed or burred in use, and the unhandy size of the head of the ordinary cap screw, especialy when desirous of using a solid or drop-forged wrench, is a matter that all machinists and engineers have met with.

There never was, we believe, any valid reason, other than economy of stock, and labor of removing of metal for making these heads so small, though probably before the application of electrical welding the cost would have been prohibitive. An electrically-welded head and body, when made of die-drawn stock, is apparently a great gain in both economy and strength.

In view of the points already mentioned, and the efforts the Cleveland Cap Screw Co. have made in the manufacture and introduction of an improved product for the use of machine

builders, in the strength, handiness, finish, etc., the Committee would recommend the award of the John Scott Legacy Premium and Medal to David J. Kurtz, the originator of the method.

Adopted at the stated meeting of the Committee on Science of the Arts, held Wednesday, January 4, 1905.

Attest : WM. H. WAHL, *Secretary*.

THE GOVERNMENT SEEKS THE CO-OPERATION OF EXPERTS.

In the business world it has long since been the day of the expert. In public affairs the day of the expert is also dawning. The need for special training and for technical advice is felt in every branch of the Government service, and it is one of the most healthful signs of the times that those who direct the great work of the Government's civil bureaus are seeking to do it by the light of the latest scientific reasons. It was in harmony with this general spirit that a meeting was recently called in Washington by the Secretary of the Interior, his invitation being indorsed by the Secretary of Agriculture. This meeting was a conference of prominent engineers and officials of the Geological Survey and of the Bureau of Forestry with certain gentlemen high in railroad and engineering circles. Problems connected with the testing of structural materials, such as stone, cement, coal, and timber were discussed. Both the Geological Survey and the Bureau of Forestry are maturing plans for extensive work in testing the character, durability and strength of these materials. With the desire of securing the coöperation of those who make practical use of the materials and who best understand the requirements which they have to meet this meeting was held.

Besides the chiefs of the Geological Survey and the Bureau of Forestry, representative superintendents, engineers, and chemists of the principal great railroads of the East were in attendance, together with representatives of the American Society of Civil Engineers and the American Society of Cement Users, the editor of the *Cement Age*, and the chief engineer of the City of Philadelphia.

It is hoped that the result of this conference will be the establishment of a continuous advisory board of experts who will assist the Geological Survey and the Bureau of Forestry in the conduct of these tests. Plans similar to this have long since been indorsed by European countries, but no such coöperation between Government and a body of experts has ever before been effected in the United States. It is hoped that the experiment will be of great practical benefit to both public and private interests.

THE DOMINION GOVERNMENT has appropriated $15,000 for the purpose of making experiments with the electric process of smelting ores and manufacturing steels. The experiments will take plate at the plant of the Consolidated Lake Superior Company, which concern will supply 400 hp. for four months without charge.

Goldschmidt's System of Alumino-Thermics.

[*Being the Report of the Committee on Science and the Arts on the Invention of Dr. Hans Goldschmidt, of Essen, Germany. Sub-Committee, Dr. H. F. Keller, Chairman; A. E. Outerbridge, Jr., H. G. Morris, James Christie, G. H. Clamer.*]

[No. 2321.]

The Franklin Institute, acting through the Committee on Science and the Arts, investigating the subject of "Alumino-Thermics," a system devised by Dr. Hans Goldschmidt, of Essen, Germany, reports as follows:

The subject of this report has been repeatedly brought to the attention of our members both at stated meetings of the Institute and of its Chemical Section. Scientific and popular accounts, profusely illustrated with experiments, of Dr. Hans Goldschmidt's inventions have been given by members of the Institute, as well as by representatives of the inventor, so that it would seem quite superfluous here to enter into a detailed description of the process or to enumerate all the various applications that have been devised or proposed by the inventor.

The sub-committee further deems it advisable to confine its report to "Alumino-Thermics" proper; that is to say, to that part of Dr. Goldschmidt's work which concerns the production and utilization of very high temperatures by means of mixtures of aluminum and with a metallic oxide, such as oxide of iron. Not only have his efforts along these lines led to the most important practical results, but they embrace all that (in the sub-committee's opinion) is novel in the process.

Of the several patents granted to the inventor by the United States Patent Office between March 16, 1897, and August 4, 1903, three relate to the joining of metal pieces, or welding, and one to a process of manufacturing homogenous metal castings. The numbers and dates of the patents are as follows:

Number.	Date.
735,244	July 21, 1899.
729,573	June 2, 1903.
717,840	Jan. 6, 1903.
733,957	July 21, 1903.

The heat-producing material, known as Thermit, is now manufactured by Dr. Goldschmidt at his Essen works on a considerable scale. It consists of an intimate mixture of finely divided aluminum and oxide of iron (or other metallic oxide), the ingredients being present in chemical proportions—

$$2Al + Fe_2O_3 = 2Fe + Al_2O_3.$$

When this thermit is ignited in one spot, the reaction proceeds with marvellous rapidity through the entire mass without any further supply of external heat. Owing to the high temperature of ignition of thermit, the reaction is started either with a bit of burning magnesium ribbon, or, better, by the aid of a special ignition powder, consisting of peroxide of barium and aluminum powder.

The extraordinary thermal effects of the reacting mass (its temperature is said to approach 5400° F.), are due to the sudden disengagement of a vast quantity of heat in a relatively small volume of material. The only products are metallic iron and oxide of aluminum, which retain practically the entire heat of the reaction, and, being liquid, separate into two layers—the metal below and the alumina-slag on top.

As already stated, the principal use of thermit is in joining metal pieces, especially of iron and steel.

Thermit-welding has been successfully applied during the past four years in a great number of cases, for some purposes on an extensive scale. Conspicuous among these uses of thermit is the welding of street railway rails at the joints for the construction of continuous track. Many thousands of such welds have been made in England and Germany, and, while the method has not so far found introduction on a large scale in this country, it has been adopted and employed for repairs of the more costly and complex parts of tracks, such as crossings, switches, etc., with excellent results, as one of the members of the sub-committee can attest from personal experience. Special mention should be made also of an advantage in thermit-welding in that it dispenses with all bulky equipment, for it requires only a few simple appliances in addition to the thermit itself. Of the latter the Goldschmidt works now supply "welding portions," each containing the quantity required for one weld. In the case of rail ends, the weld is made by bringing

the molten iron resulting from the reduction of the thermit in direct contact with the rails, so that it will adhere to the parts to be joined, and thus unite them.

Another method of thermit-welding, applicable to wrought-iron pipes and angle iron, depends entirely upon the heat obtainable from thermit, the reduced iron not being allowed to adhere to the welded parts. To this end it is only necessary to apply the molten thermit mass in such a way that the slag (alumina) first comes in contact with the cool surface of the articles so as to form a protecting layer, and thus prevent the metal which follows from adhering. While the ends of the pieces are brought to the welding temperature, the weld is produced by aplication of pressure, but without disturbing or changing the section of the welded parts.

Thermit welding has also proved most valuable as a means of repair in break-downs of machinery. Many cases have been reported where otherwise exeedingly difficult, if not impossible repairs were made by its means, and so far as the sub-committee is able to ascertain, with remarkably uniform success. It is to be noted in this connection that the repairs which have been made by the aid of thermit include smaller operations, such as replacing a tooth in a steel wheel, as well as the welding of very large pieces, like the stern-posts and crank-shafts of trans-Atlantic steamships.

Still another ingenious application of the thermit reaction is in preventing the formation of cavities in large steel castings. A box of specially-prepared, so-called anti-piping thermit, attached to an iron rod is pushed into the ingot, just as a crust is beginning to form. The heat produced is sufficient to keep the metal liquid where the piping occurs and allows more liquid metal to be poured in to fill the cavity.

It is the opinion of the Sub-Committee that the invention of thermit and its application in welding and casting metals, constitutes a great step in advance in the production of utilization of high temperatures. While it is recognized that Dr. Goldschmidt was not the first one, either to observe or to apply the heat liberated in this reduction of metallic oxides with aluminum, he must be credited with having developed the manufacture of thermit, with the practical application of the enormous heat energy stored in this product, and with extraordinary per-

severance and resourcefulness in bringing these inventions to commercial success and thereby creating a new industry.

The chief obstacle to the more extended use of thermit in this country has been the rather high price of the article with the added import duty. It is to be expected, however, that this barrier will be removed as soon as thermit can be supplied by an American factory.

The sub-committee unanimously recommends the award of the Elliott Cresson Medal to Dr. Hans Goldschmidt for his inventions in "Alumino-Thermics," by the Franklin Institute.

Adopted at the stated meeting of the Committee on Science and the Arts, held Tuesday, June 21, 1904.

Attest: WM. H. WAHL, *Secretary.*

NICKEL STEEL.

Nickel steel has of late received special attention, and has been investigated by engineers in relation to its usefulness as a structural material. For many years metallurgists have experimented on the effect of the addition of special metals to steel with a view to increasing the ultimate strength and elastic limit of the steel without proportionately decreasing its ductility. So far, as a special structural steel, nickel steel is the only one which has proved satisfactory.

Nickel steels of varying carbon and nickel have been successfully used during the last fifteen years for marine and stationary engine shafting, locomotive axles, piston rods and crank pins and a wide variety of forgings and castings for parts of machinery. Its application for the manufacture of armor plate since 1890 is well known. It has recently been adopted, especially in this country, for gun forgings. It has been proposed for structural work before, but is now actually used for bridge construction in the eye bars for the Blackwell's Island cantilever bridge across the East River, New York City, and may take an important place as a structural material for long-span bridges.—*Iron Age.*

THE BARNARD MEDAL has been awarded this year by Columbia University, New York City, to Henri Becquerel, of Paris, France, in recognition of his important discoveries in the field of radio-activity and for his discovery of the dark rays from uranium. The award comes once in five years, and has been made on the nomination of the National Academy of Sciences.

A LARGE VIADUCT is to be constructed across the river Indus at Khushalgrah, one of the largest rivers in India. The bridge is to be of the double-deck type, carrying the railway on top, with the roadway beneath. It will have 470-foot cantilever span and an "anchor" span of no less than 603 feet.

CHEMICAL SECTION.

*Mica and the Mica Industry.

By George Wetmore Colles.†

[The subject is treated in eight principal captions: Migerology, geology, geographical distribution, history, mining, uses, statistics and conclusions. The treatment is industrial rather than theoretical or scientific, and aims at setting forth the present, past and probable future of mica-mining in this and other countries. The present instalment includes the first of the above captions, dealing with the characteristics of the various species of mica.—The Editor.]

The object of this paper is to present in connected form whatever may be of interest on the subject to those industrially or commercially interested in mica. Unlike the grander mineral products, such as coal, iron and copper, concerning which volumes have been and are constantly being written, the mineral mica has not yet received any treatment at all from writers, other than a local, partial or superficial one. Nor is it strange that this should be the case; for it is well within the memory of living men that mica as a commercial product has emerged from a condition of too diminutive proportions and too localized to be called an industry, to the occupation of a very respectable place in the industrial world, and one of ever-growing importance.

In approaching the subject of mica the investigator is immediately confronted with an obstacle which is apt to discourage him at the start. I refer to the fog-bank of mystery which overhangs the whole subject, and which may prove well nigh impenetrable to one not himself engaged in the industry as either buyer, seller or miner. You ask why? and echo answers wherefore. Perhaps it is a relic of the North Carolina secretiveness spread over the country at large. As well ask a Carolina mountaineer about the moonlight stills of his neighborhood as about the mica mines which they intersperse. But I do not refer merely to the miners. The large dealers and users refuse information of any kind, and a few sporadic exceptions

*Read by title.

seem only to prove the rule. Two of these exceptions (both in Canada) deserve special mention. I refer to the Blackburn Brothers, to whose mine in Ottawa County, Quebec (the largest in the Province), I not only was given access, but assisted in my examination of the entire property, and shown every courtesy; and the General Electric Company, of Schenectady, N.Y., to whom I am indebted for an equal degree of courtesy and the privilege of a tour of inspection through the great Lacey mine, one of the richest, if not the richest, mine in the world. To these firms I desire to express by thanks.

It shall be my main thesis to show, in the following pages, that the mineral mica, industrially considered, embraces not one, but rather *two* distinct mineral products; and that the mica *industry*, as a whole, comprises in reality a group of several distinct industries which have little in common.

I. MINERALOGY.

The term mica embraces a group of minerals all of which have certain very marked characters in common. Chemically speaking, they are hydrous, but not strictly speaking hydrated,* compound silicates of the base aluminum in combination with potash, soda, iron, manganese, magnesia or lithia; or rather of several of these bases, for they are practically never found alone. Lime, baryta, strontia, and some of the other elements* occur occasionally in small quantities, but ought to be looked upon as accidental and as not properly belonging to the mica group. In addition, fluorine generally enters to some extent (from nothing in most muscovite to a maximum of 9 per cent. in the lithia micas) probably combining with one of the metallic bases to form a compound radicle. Until very recently

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*I here use the term *hydrous* to designate rocks which contain the elements of water; *hydrated* to designate those having water of crystallization so called, that is, water for which a place cannot be found in a rational chemical formula.

*Rubidium and caesium accompanying lithia; chromium accompanying manganese; boron, titanium, copper, chlorine, and even carbon in one specimen of muscovite, are enumerated in the analyses collected by Dana; also vanadium, the principal constituent of *roscoelite*, a mica occurring in auriferous quartz in California.

mineralogists have been at a loss to reduce the micas to any satisfactory common formula, which would be found applicable to them all, as the rather futile hypotheses of Tshermak demonstrate; but the studies of F. W. Clarke* have shown that this is possible without too great complication. This formula is $R_{3n}Al_{4-n}(SiO_4,Si_3O_8)_3$ in which "n" has any integral value from 1 to 3, and R is a univalent radicle. This formula when expanded may assume any one of the following forms: $R_3Al_3(SiO_4,Si_3O_8)_3$, $R_6Al_2(SiO_4,Si_3O_8)_3$, $R_9Al(SiO_4,Si_3O_8)_3$, or for a dyad radicle Mg replacing the monad R formulas 1 and 3 would of course be doubled. In graphic symbols the various compounds would be written as follows, representing by X the tetrad radicle SiO_4 or Si_3O_8:

$$1.\ Al\begin{array}{l} X\equiv R_3 \\ -X\equiv Al \\ X\equiv Al \end{array} \qquad 2.\ Al\begin{array}{l} X\equiv R_3 \\ -X\equiv R_3 \\ X\equiv Al \end{array}$$

$$3.\ Al\begin{array}{l} X\equiv R_3 \\ -X\equiv R_3 \\ X\equiv R_3 \end{array} \qquad 4.\ Al\begin{array}{l} X\equiv Mg\,R \\ -X\equiv Al \\ X\equiv Al \end{array}$$

$$5.\ Al\begin{array}{l} X\equiv Mg\,R \\ -X\equiv Mg\,R \\ X\equiv Al \end{array} \qquad 6.\ Al\begin{array}{l} X\equiv Mg\,R \\ -X\equiv Mg\,R \\ X\equiv Mg\,R \end{array}$$

$$7.\ \begin{array}{l} Al \\ \\ Al \end{array}\begin{array}{l} X_2\equiv Mg_3 \\ X_2\equiv Mg_3 \\ X_2\equiv Mg_3 \end{array}$$

The univalent radicles represented by R may be either the simple metals, such as Na or Li; or the compound radicles MgF, MgOH, AlF_2 and AlO. The dyad radicles are Mg, Fe and Mn. The only triad radicle aside from aluminum is that of iron, which in that of the ferric state may replace a portion of the aluminum.

For such of the micas as are metasilicie, that is, contain an excess of SiO_2 above what is required for an orthosilicate, Clark resolves them into compounds of orthosilicates and polysilicates whose acid radicle is Si_3O_8, which is tetrabasic, the same as the radicle SiO_4. Micas of this composition are termed by Clarke "phengitic," and this seems a reasonable

*Am. Jour. Sci., Volume cxxxviii, page 384, Volume cxl, page 410.

means of explaining their constitution by a rational formula.

The respective formulas for the separate species of the mica group will be given separately below.

A careful consideration of the various kinds of mica, both from a chemical and physical standpoint, shows that they fall into two natural groups characterized (1) by the atomicity of the principal bases, uneven or even, here denominated respectively *perissad* and *artiad* micas (from the Greek words for "odd" and "even"); (2) by the character of these bases, alkaline or magnesian; (3) by the mineralogical environment in which they occur, granitic of pyroxenic; and (4) by their supposed mode of origin, igneous or aqueous. The principal kinds of mica may be thus classified as follows:

PERISSAD MICAS.

(Alkaline, Granitic, or Igneous Micas.)

Muscovite,	potash mica,	$H_2KAl_3(SiO_4)_3$.
Paragonite,	soda mica,	$H_2NaAl_3(SiO_4)_3$.
Lepidomelane,	ferric iron mica,	$(H,K,AlO)\ Fe_n(Fe,Al)_p(SiO_4)_q$.
Lepidolite,	lithia mica,	$KLi\ [Al(OH,F)_2]\ Al(SiO_3)_3$.

that is: $HKLiAl_3(SiO_4)_3+K_3Li_3(AlF_2)_3Al(Si_3O_8)_3$.

ARTIAD MICAS.

(Magnesian, Pyroxenic, or Aqueous Micas.)

Phlogopite,	magnesia mica,	$(H,K,MgF)_3Mg_3Al(SiO4)_3$.
Biotite,	magnesia iron mica,	$(H,K)_2(Mg,Fe)_2Al_2(SiO_4)_3$.
Zinnwaldite,	lithia mica,	$(K,Li)_3Al(OH,F)'_2Fe''Al_2(SiO_4,Si_3O_8)_3$.

It is of interest and importance to note that the crystallographic characters of the micas throw them into a corresponding and substantially identical classification; but with the possible exception of lepidomelane, which E. S. Dana places in the second class; but, as hereafter noted, there seems to exist considerable doubt as to what is meant by this term.

It is important to note that the names and formulae given above designate *types* rather than any sharply-defined chemical compounds, like calcite or quartz. It may be taken that the actual minerals never conform precisely to these formulas, and pass by gradations from one to another, so that it becomes diffi-

cult to delimit individual species. A large number of subordinate varieties have been described, which, however, are of no importance to our present purpose.

All the micas contain a small proportion of water, although sometimes falling to below one per cent. The actual amount is very variable. This water is to be considered water of constitution, that is, as constituting an integral part of the mica. This water is given off on heating under ordinary pressure.

Physical Characteristics.

The most striking characteristic common to all the micas is the quality of being easily cleavable into thin, elastic and generally transparent plates, and in this characteristic they find their economic usefulness. Mica is necessarily a crystalline mineral, and although many of the species, notably those of the second class, imitate the hexagonal system of crystallization (which possesses four axes, three of which line in one plane at angles of 60°) they all belong to the monoclinic system, having but three crystallographic axes, two of which make an oblique angle and are at right angles to the third. The micas of the first class, where they occur in sizes of economic importance, are found in blocks which are theoretically short rhombic prisms of 60° angle, though practically this form is obscured by the rough exterior, due to their mode of origin. But in granite, where the crystals are limited to the area of a square inch, we find them as a pile of hexagonal plates with clean-cut edges, and these plates are often spread apart at one side, so as to give a plumose effect, and leaving voids in the rock. In micaceous, schists and gneisses, mica occurs as individual scales (frequently of sedimentary origin) and in irregular small masses. There are many other forms of minor importance, which have been found in various rocks.

The natural form of micas of the second class is a hexagonal prism, the sides of which are, however, as a rule, unequal. The axis of the prism in each case is the oblique crystallographic axis, and the cleavage plane for the plates is that of the other two axes or base of the prism. There seems to be no practical limit to the possible thinness to which the plates can be split, other than the physical possibility of splitting them. Plates

are easily obtained one-thousandth of an inch thick, and have been split, although not in plates having any considerable extension, to a thickness of three hundred-thousandths of an inch —about one-thirtieth of the thickness of ordinary tissue paper.*

That mica has a very strongly characterized polarity can be readily observed by striking a mica plate with a dull-pointed instrument on a yielding surface, which will cause the mica to become fractured. The lines of fracture extend in one or more of three principal directions, which make angles of 60° with

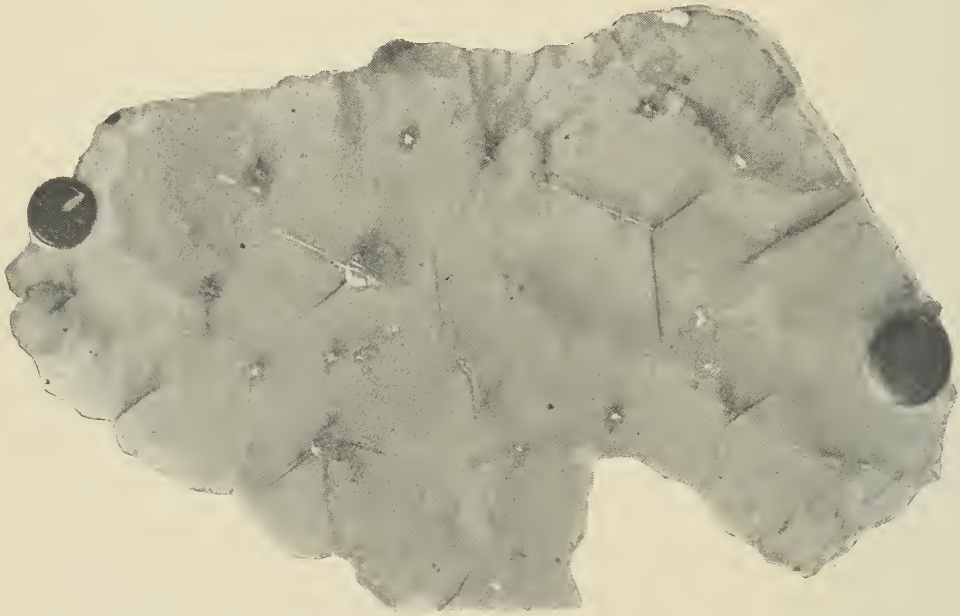

Fig. 1. Percussion-figures in muscovite.

each other and are perpendicular to the crystalline edges of the plate, and one of which is parallel to the clinopinacoid plane (the plane of symmetry of the crystal); or in one or more of three secondary directions, which are parallel to the edges of the crystal and bisect the angles formed between the first. When complete a six-rayed star, called the *percussion figure*, is produced, although often only two or three rays appear.*

A distinction is often made between a percussion-figure hav-

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*According to Jefferson & Dyer in Trans. Am. Inst. Elec. Eng'rs, 1892.

*A simple way of producing a percussion figure is to take a wire nail, hammer the point upon an iron surface so as to dull and round it off, place a mica plate not exceeding one-sixteenth of an inch in thickness on a sheet of paste-board, wood, or other yielding surface, place the point of the nail on the mica plate and give it a light blow with the hammer, sufficient to fracture the plate slightly.

ing one of these sets of rays, and a *pressure figure* having the other set. By repeated experiments, however, I have not been able to discern any definite distinction of this sort. Rays produced by pressure generally correspond with the rays produced by percussion. In Figure 2 is reproduced photographically a

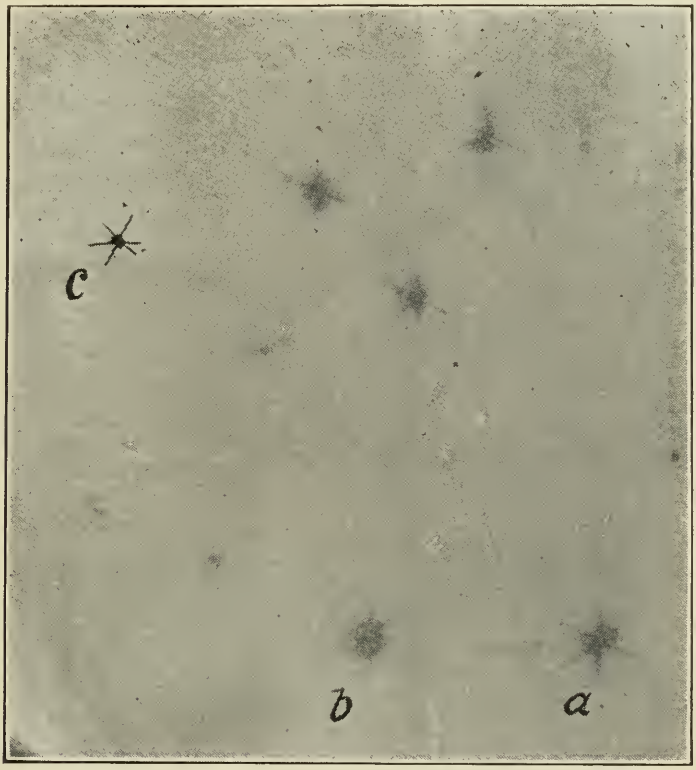

Fig. 2. Percussion-figures in muscovite. × 2.

plate of mica having three asterisms, a, b and c; *a* and *b* both have rays of the first set, although *a* is a percussion-figure and *b* a pressure-figure, while *c* is a percussion-figure and yet has rays of the second set. The three sets are all included within a circle of less than one inch diameter. Note also a single secondary ray (horizontal on the right) in the asterism *a* bisecting the angle between two of the primary rays.*

Another indication of the strong hexagonal polarity of mica is seen in the ruling and striation which often occurs in one or more of the three *secondary* directions, *i. e.*, parallel to the edges

*It is not easy in practice to show the asterism in the softer micas, because the instrument, instead of cracking the plate, simply pierces a hole therein. The more brittle the mica the clearer will be the asterism.

of the crystal. The striations may be excessively fine, so as to require a glass to distinguish them, and show as fine, opaque lines as if due to parallel scratches. Inclusions are also frequently arranged with their principal directions parallel to those of the mica, as exemplified by the quartz crystals in Figure 3 and the rutile needles in Figure 4.

Such polarizations mark the traces of secondary cleavage or gliding *planes*, which make an acute angle with the planes of the plates.* These planes can be readily discerned on the straight edge of a thick plate. To them also is due the fact that mica cannot be cut smoothly with a knife-blade or saw held perpendicular to the surface of a plate. No matter how sharp the

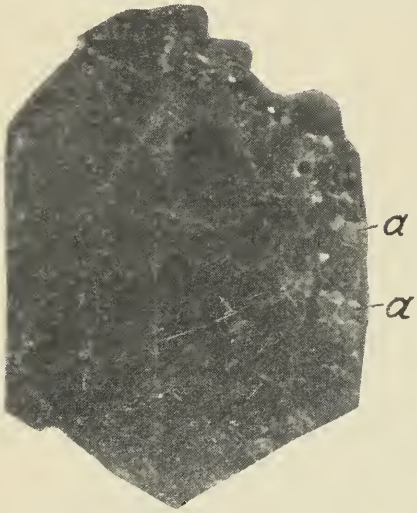

Fig. 3. Black Mica with hexagonal quartz crystals (as *a*) traversing and honeycombing the plate.

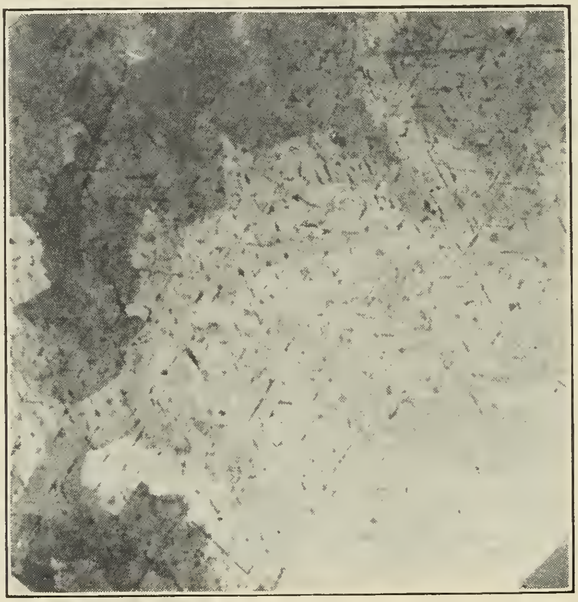

Fig. 4. Black Mica (biotite) with rutile(?) needles. ×2. Note that needles are oriented at angles of 60 deg. (principal directions), but a few bisect these angles (secondary directions).

cutting edge may be, a jagged and torn surface always results.

The micas are all of a very soft nature, having a hardness va-

*These planes are inclined about 67 deg. to the principal cleavage plane.

rying from two to three on the mineral scale; that is, between gypsum and calcite. They can readily be scratched with iron or steel, and even with the finger-nail in some cases. The granitic micas are harder and more brittle in character than the pyroxenic and also slightly less cleavable—they cannot be split so neatly, cleanly or thinly.

Most kinds of mica are practically infusible in ordinary heats. Before the blow-pipe some of them, especially the lithia micas, are fusible with difficulty, yielding up a portion of their water. A very intense heat, as that of the electric arc, will cause the mica to whiten and crumble locally, and even a low degree of heat sufficiently prolonged, as in a stove or furnace wall, causes the mica to lose gradually its elasticity and become brittle and friable. The softer pyroxenic micas are more easily decomposed by water than the granitic. Mica has an unctuous or talc-like feel, which is most observable when ground, and renders it very useful as a lubricant. It is thought that this condition is due to the perfect smoothness of the laminæ, which is implied by the very perfect cleavage which it possesses.

Mica may be clear or opaque, but by clearness is to be understood that of a piece one-eighth of an inch thick, or less. Transparent micas in thick pieces appear opaque with a rich black luster, of whatever color they may be. The reason for this is to be looked for in the innumerable cleavage surfaces which reflect successive portions of the light until it is all reflected at a very slight depth. To ascertain the color of a piece of mica, it must be seen by transmitted light in a plate from one-sixteenth to one-eighth of an inch in thickness. Plates thinner than this often seem to be colorless. Opaque micas in thick blocks do not exhibit the rich black luster of the transparent micas, but have a metallic reflection. Such micas are opaque, or nearly so, even when seen in thin laminæ.

Muscovite is the commonest of all the mica types, and it is variously known as potash mica* and biaxial mica, and form-

**Potash* mica, because there is no other base to distinguish it by. It contains no more potash than other micas. All micas (except paragonite, a semi-mica) contain from 4 to 14 (generally 8 to 10) per cent. of potash; but one specimen of muscovite is cited (No. 32 on p. 618 of Dana's Mineralogy, 6th Ed.) which contained none at all, its place being taken by 4.17 per cent. of *lime*. It was still muscovite, apparently, and not margarite, as theoretically it should have been.

erly as muscovy glass, from which its technical name has been derived. The clear kind is known to the trade as "water mica," and this, as a rule, contains no iron, but much of the large-sized muscovite is unfortunately colored to some extent, which detracts greatly from its value. It is often, moreover, streaked, which still further decreases its value. The colors are apple green, dark olive green, also yellow, gray, brown and, according to E. S. Dana, violet and rose-red. It seems to pass over indefinitely into the iron mica which is herein termed lepidomelane. A great number of varieties have been specified which connect this type of mica with others and with different minerals, but which are of no importance for the present article.

Paragonite is a soda mica, or semi-mica, corresponding precisely to muscovite in composition, and occurring in a few places on the continent of Europe, but of no importance to our present purposes, as it occurs only in massive form or minute scales.

Euphyllite is a sodium-potassium variety, intermediate between paragonite and muscovite, having a laminaceous structure, but imperfect cleavage.

Lepidomelane is a name of somewhat uncertain application, but here designating the type ordinarily found in granitic rocks and their derivatives is a similar environment to muscovite. This mica has been termed biotite by most authors,* but it is certain that it is very different in its physical characters from the biotite found in the magnesian rocks, and resembles muscovite in everything but color. According to William B. Phillips,* Dr. F. A. Genth states that he has never seen biotite in mica veins (meaning the pegmatite dikes), which would indicate that he characterized the mica in question as merely a discolored variety of muscovite. It may be that the black mica which is of frequent occurrence in granites is really biotite and a ferromagnesian mica, in which the iron is generally in the ferrous

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*J. D. Dana (Manual of Geology, 3d Ed., p. 71) for example, classes "biotite" (= lepidomelane) as a "potash-mica;" this may be offset against the classification by his son, E. S. Dana (Descriptive Mineralogy, 6th Ed., § 462), of biotite as a magnesia mica.

*In Engineering and Mining Journal, April, 1888.

condition; but this mica is always of small size and accompanied perhaps with other amphibolic magnesian minerals, like augite or hornblende, while the pegmatite does not, so far as I know, contain these minerals. Lepidomelane, as shown by the formula, is of exceedingly complex besides very variable constitution, but characterized by the predominance of ferric iron and general basic qualities. It is in color usually black and somewhat brittle. It is inferior to other micas for electric purposes, and unsuitable for almost all others.

Lepidolite is a lithia mica, containing 4 to 6 per cent. of that base, as well as a large percentage (5 to 8 per cent.) of fluorine. It is almost always associated with muscovite and often crystallizes on or is intercrystallized with the latter. It appears to be the principal product of the Indian mines of the Hazaribagh district, in Bengal, and is highly esteemed as an electric mica for its toughness, flexibility and freedom from flaws, and is also apparently the kind almost exclusively used (at least until recently) in Europe for glazing purposes. It is generally of decided color—rose-red, purple, violet, gray, lilac, brown or yellowish; but also found colorless. In luster and transparency it is somewhat inferior to muscovite, but in thin sheets is quite transparent. It is notable for being the most important and practically the only commercial ore of lithia.

Phlogopite is the characteristic type of what is known to the trade as amber mica. It is, as a rule, of a marked and characteristic amber color, varying to yellow brown, greenish, etc. Commercially, three distinct varieties may be specified, to wit: (1) clear amber, transparent, soft; (2) mottled, medium in hardness; (3) milky, hard, opaque. The milky variety has a sheen like silver, for which it might readily be mistaken at first glance. The several grades are valued in the order named, the softest being the most useful for electric purposes. The appearance of milky mica is apparently due to fine mottlings which cover its surface, as can be seen by examining a thin lamina under a glass. These mottlings are similar to those of the mottled variety, except in their minuteness; they are irregular, whitish blotches—sometimes, perhaps, developing into minute striations, but not necessarily so.

Biotite is a ferro-magnesian mica, a part of the magnesia being replaced by ferrous iron, therefore of more general occurrence

than the pure magnesia mica. It is now apparently little used, probably on account of the abundance of the amber mica, which renders it unprofitable. This discrimination against biotite is believed to be largely based on prejudice. Biotite in large crystals has a luster of great brilliancy and irregular lines and spots or iridescent reflection frequently cover the surface.* I have seen immense plates of brilliant black biotite without a flaw of any kind; but it must be admitted that it is very apt to become rust-streaked and rotted in the ground, owing to the oxidation of the iron to the ferric condition, to which it is very subject when exposed to the joint action of water and air. A considerable number of varieties have been specified.

Zinnwaldite is a lithia mica corresponding to lepidolite, but containing, in addition to lithia and fluorine, from six to twelve per cent. of ferrous iron. In color it varies between various shades of brown, violet, yellow and gray. It occurs in only a few places, and is of no economic importance. Cryophyllite and polylithionite are specified as varieties.

Pholgopite and biotite are both distinguished from the other varieties by the comparative ease with which they absorb moisture and rot when lying on the surface of the ground. When found within a short distance of the surface they appear at first glance to be the same as other mica, but can be readily crumbled in the hand and crushed to a soft mud. The same is not true of the granitic micas, which may lie for an apparently indefinite period on the surface without noticeable change. This quality has an important bearing on the economic situation. The rock in which the granitic micas are found, on account of its hardness, makes their mining a task of great difficulty, but it often happens that the enclosing matrix is completely disintegrated leaving the mica intact, and where such is the case the extraction of mica is a matter of comparative ease. Again, the quality of mica in a pegmatic lode can be readily ascertained from surface indications; such, however, is not the case with the magnesian micas, as they change repeatedly in character

*These lines are also of frequent occurrence on amber mica. Their position is readily changed by rubbing the surface, and they may be wiped off altogether. The most probable explanation of these iridescent lines appears to be the presence of a hygroscopic iron salt in visicular inculsions.

with depth. Moreover, it is frequently necessary to perform a large amount of excavation before it can be learned whether the lode contains mica of value. Phlogopite and biotite are both completely broken up and dissolved by sulphuric acid, the silica being left behind.

Mineral Relations of the Mica Group.

It is of interest and importance, especially when we come to consider the origin and true nature of the micas, to take a brief survey of the place occupied by them with respect to other minerals. At the outset let it be noted that the micas, besides blending with one another, pass in like manner by indeterminate gradations into other related and similar forms. As silicates, they stand midway between the anhydrous silicates on the one hand, of which the feldspars are examples, and the hydrated silicates on the other, of which the zeolites are most characteristic. The feldspars, like the micas, are compound silicates of aluminum and another metal, ordinarily an alkali. These contain no water, and consequently can give off none by heat. The zeolites, on the other hand, also compound silicates of aluminum and an alkali or alkaline earth, invariably contain the elements of water in the molecule, and this water is given off on heating. The feldspars are characteristic of igneous rocks, forming an almost invariable constituent of lavas and intrusive rocks. The zeolites are considered to be secondary products of the same rocks, occurring in igneous rocks such as trap and ordinary lava, but have been formed by the action of water since these rocks became cold. Likewise, in hardness, the micas lie between the harder feldspars and softer zeolites.

From another side we have the clays, the base of which is kaolin in pure form, consisting of the mineral kaolinite. The clays are hydrous *aluminum* silicates, and are secondary products of feldspathic rocks formed by the leaching out of the soluble bases, potash and soda.

The three groups most closely related to the micas, however, are (1) the vermiculites, or hydrated micas, (2) the brittle micas, and (3) the chlorites.

The vermiculite group comprises derivation products of the true micas formed by the latter taking up water, and they have

a very similar appearance with a more or less perfect cleavage; but the plates are soft, imperfect and non-transparent, and have not the toughness of true mica.

Among the brittle micas the principal form is margarite, whose chemical formula conforms to the theoretical general formula given for mica, except that the alkaline base is calcium, which is not a constituent of the micas proper. This semi-mica possesses also brittle, non-transparent plates.

The chlorites resemble most closely the second class of micas in being compound silicates of aluminum, magnesium and ferrous iron—the last two replacing one another in indefinite proportions, and ferric iron also occurring in substitution for aluminum. The crystallization is similar to that of mica. Beyond the chlorites we approach the strictly magnesian and calcic silicates—epidote, pyroxene and amphibole. Among the best known magnesian silicates associated with these are hornblende, soapstone, talc, tremolite, asbestos and serpentine.

We see that the micas divide themselves clearly on the lines of feldspathic or igneous rocks on the one hand and pyroxenic or magnesian on the other, and it will be seen later that the distinction is fundamental, whether from a geological or economic standpoint.

Pinite is a name given to a number of soft, massive minerals, having indeed, no superficial resemblance to mica, but corresponding pretty closely to muscovite in composition,—alteration products of various silicious rocks. It is probably to be regarded as a massive, compact variety (of muscovite), usually very impure from the admixture of clay and other substances.* If opportunity were given to it to recrystallize under proper conditions, mica would doubtless result. This will serve to explain the origin of mica in many cases.

It is noticeable that all the more important of the minerals above enumerated—including orthoclase, feldspar, the zeolites, vermiculites, chlorites, margarites, kaolinite, serpentine, talc and pyroxene (but not amphibole), crystallize on the monoclinic system, and many of them are characterized by thin, hexagonal plates, and have other more or less close resemblances to mica.

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*E. S. Dana, Mineralogy, p. 621.

Artificial Micas.

It is interesting to note that many of the principal varieties of micas have been obtained artificially. By fusing various natural silicates (hornblende, actinolite, glaucophane, andalusite, garnet, etc.,) with the fluorides of sodium and magnesium, micas corresponding to biotite, phlogopite, muscovite and zinnwaldite were obtained. Khruschoff describes the formation of margarite, biotite and muscovite by fusing various bases with the constituents of lepidolite, and an excess of silica, alumina and alkaline fluorides. Vogt, of Sweden, also describes the occurrence of mica in slags. Notwithstanding this,

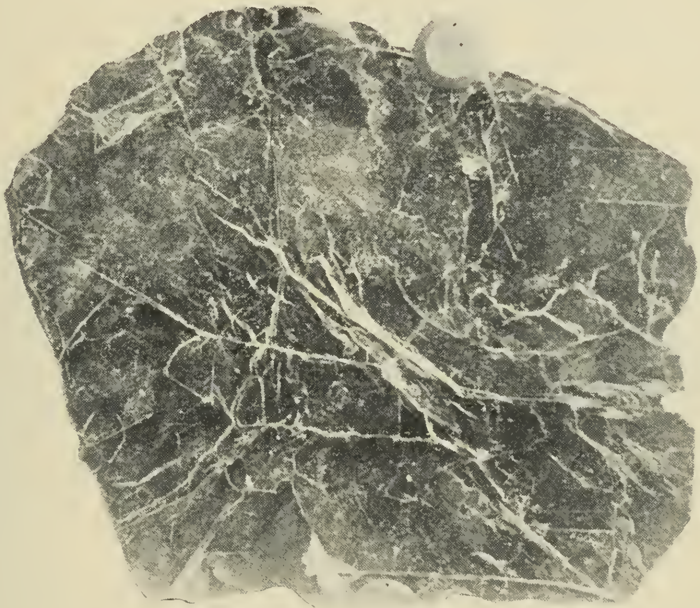

Fig. 10. Mica-plate heavily creased by earth forces. Much of the magnesian mica is found in this condition, and is, of course, worthless as sheet.

however, there is not the least likelihood of artificial mica being produced on a commercial scale at a profit. These experiments merely explain to us some possible modes of origin of natural mica.

Defects.

From an industrial standpoint the defects of a sheet of mica will, of course, depend on the uses to which it is to be put. The most general defect, however, which lessens the value of the mica for whatever purpose, is flaws. Although a sheet of mica may be several square feet in extent, flaws extending across it,

or through it, may render its value per pound even less than that of much smaller sizes. Generally speaking, the value of mica grows in proportion to its size, clear of defects, the smallest size of sheet-mica in commercial use being that which will cut in rectangular sheets 2x2 inches without flaws, and anything smaller than this being classed as scrap.

Flaws in a sheet of mica arise, generally speaking, from the stresses to which the crystal from which it was taken has been subjected while still in the ground, and which cause the same to be bent, folded, or creased, and thus give rise to cracks. A crack or crease extending across the plate may be said to divide the plate for industrial purposes at that point. The main task of the mica sorters, in sorting mica according to size, is to

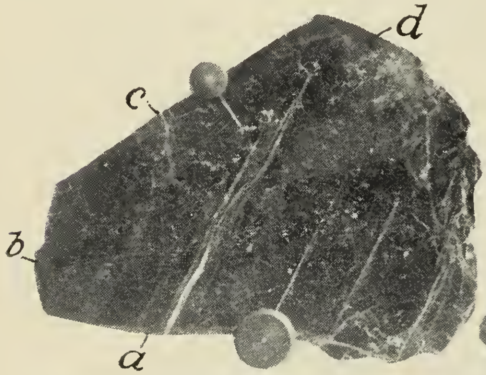

Fig. 11. Mica-plate creased on principal planes, making an angle of 60 deg. with the clino-pinacoid *a*. *b*, *c*, *d*, crystalline edges.

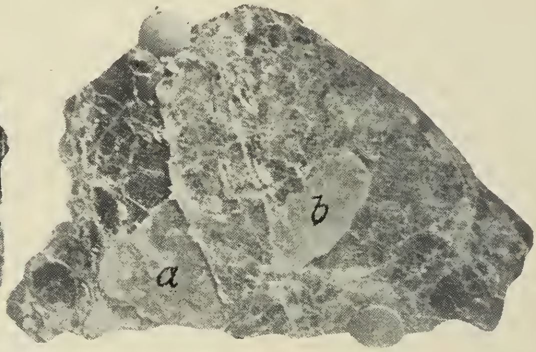

Fig. 12. Amber mica with intruded quartz laminae, *a*, *b*.

quickly distinguish all cracks and other flaws and trim them away from the plate.

Inclusions give rise to another kind of flaw, which result in holes in the plate, and of course render that portion of it worthless. Small crystals of quartz or calcite may occur traversing the plates (Fig. 3); these were evidently in the crystal at the time it was formed, but, on the other hand, flat crystals are sometimes found between the plates, which were intruded after the crystal was formed. It is quite common to find films of massive quartz, as in Fig. 12, almost as thin as the mica laminæ themselves, projected between them. The quartz was *not* forced between the plates like a wedge, but was deposited in a void previously existing there.

Another variety of inclusions is minute crystals of black ox-

ide of iron, a very common feature of black granitic mica, and one which practically destroys its value, because they cannot be got rid of at a reasonable expense. If used for electrical insulation, they would form paths for the puncture of the plate; whereas for glazing purposes, they destroy its appearance. These crystals appear for the most part to arise from the iron carried by the mica itself. The iron micas generally, as previously indicated, are quite liable to defects, not only of this kind, but to similar ones, resulting from the vacillation of the contained iron between the ferrous and the ferric state. Rust streaks are of very common occurrence, and streaks, checks and other marks, also occur, which result from the irregular distribution of the iron, and naturally make it valueless for glazing purposes. For example, a plate of mica will be half black and half colorless divided along one of the lines of polarization; or series of black lines will occur parallel to one or more of the edges of the crystal.

Ruling (Fig. 13) is a common defect in the granitic micas, which likewise destroys the value for every purpose except grinding, of what would otherwise be mica of excellent quality. When a ruled block is split the marginal portions will fall away in ribbons parallel to one of the edges; or occasionally parallel to both edges ("double ruled") resulting in the latter case in small rhombs or lozenges (Fig. 14). The existence of this condition means simply that the crystal has been subjected to shearing forces, which have resulted in a partial cleavage along one or more of the secondary cleavage-planes of the crystal. This defect is most common in the granitic micas, and is one of the indications which go to show the conditions under which they were formed.

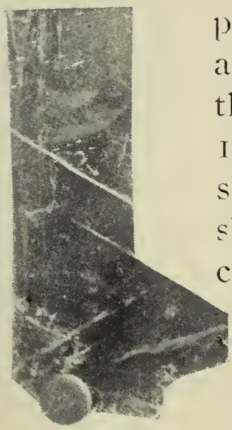

Fig. 13. Ruled amber mica.

That the necessary shearing stresses to produce this result should have arisen during the folding of the rocks, which followed the formation of the mica dikes, is almost a matter of course. Ruled mica is not found in isolated crystals in these dikes, but all the mica of the vein, or of a considerable portion of it, will be found in the same condition; and this applies not only to ruled mica, but to other defects likewise. All the mica

at a given point is of the same general character, and suffers from the same defects.

Although ruling of this kind is not common in the pyroxenic micas, it is not uncommon to find the edges of crystals of the latter kind finely divided by parallel planes—so finely, in fact, that the substance of the crystal can be readily crushed into a fibrous material similar to asbestos, though, of course, of a coarse and brittle nature (Fig. 15). It seems, however, quite impossible that this fibrous condition should have been produced by strains extending through the mass of the rock, or, indeed, by any strains at all, as it is of isolated occurrence.

Fig. 14.
Lozenge of ruled biotite.

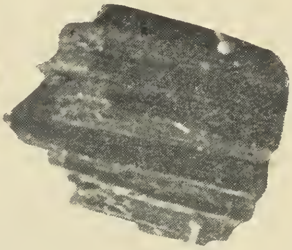

Fig. 15.
Fibrous mica (magnesian).

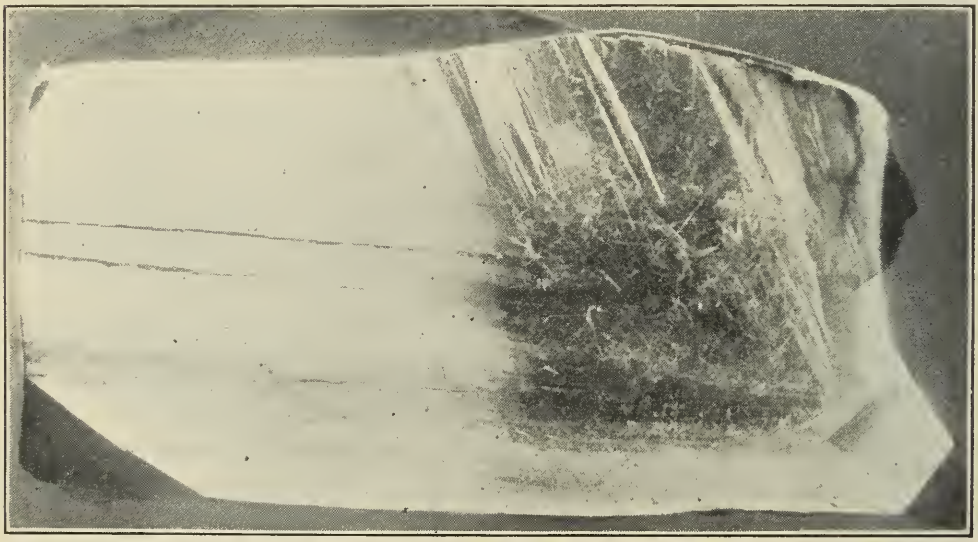

Fig. 16. A-mica (by transmitted light). For some reason a dark blotch appears over part of the thickened or welted portion, but does not extend over the remainder. No such blotch is visible to the eye. Presumably due to a pleochroic refraction.

Allied to ruling is the defect known as "A"-mica, which is mica having the edges of the crystals corrugated and of uneven

thickness for a considerable distance inwardly. The corrugations on two adjacent edges making an angle of 60° give the appearance of a letter A, without the middle bar; it would be more properly called "V-mica." As indicated by the section of the plate in Figure 16, a plate of A-mica will show a welt of increased thickness running through the corrugated portion. The internal plates do not extend beyond the inside of this welt and the welt itself may comprise strips of uneven thickness intercalated between the plates which extend across. Obviously this cannot be the result of pressure alone, and some other agency acting during the formation of the crystal must be relied on to explain it. A-mica, like ruled mica, is characteristic of the granitic varieties.

Wedge-mica is another common defect to which granitic micas are subject, but I believe it also occurs in a somewhat different form in the pyroxene formations, in which, however, it does not play an important part. A block of wedge-mica is thinner at one end than at the other, and the plates split therefrom are likewise thinner at one end than at the other, and some of the individual laminæ do not extend all the way across the plate. The mica of the Godfjeld mine, on the southwest coast of Norway, is of this character. The cause of this defect is somewhat mysterious, but it is undoubtedly to be looked for in the irregular action of the crystallogenic forces.

While specked mica is valueless for any purpose, ruled, A-, and wedge-mica, if not otherwise defective, have a value as scrap; but this value is not sufficient, as a rule, to make it pay to mine them. When a lode is found with mica thus defective, it is simply passed by. Specking, on the contrary, does not always become general, or prevent good mica from being taken from the same place; it may be confined to a limited region near the surface.

Color is a defect only for certain purposes, as for stove-glazing, and, when ground, for decorating purposes. Perfectly colorless mica bears the highest value for these purposes, although much of that which is used has some color, as for example, the ruby mica of India, and the somewhat smoky product of New Hampshire. The tints of these in thin sheets are not perceptible to the eye, but they do exercise a decided influence on the amount and quality of transmitted light. Mica

having a comparatively light tinge of green is deficient in quality for use as a decorative ingredient in paints.

[*To be continued.*]

THE PANAMA CANAL SITUATION.

Referring to the unfortunate complications that have arisen in connecion with the commencement of the work on the Panama Canal, the *Scientific American* makes the following editorial comment:

"The most ardent advocates of the Panama Canal must admit that, admirably as the government has handled the matter of the purchase of the Panama Canal property, it has made something approaching to a pitiful fiasco in its attempt to commence actual construction of the canal. * * *

There is absolutely nothing in the Panama situation to prevent the application of the railroad methods of organization in carrying the work through. As far as the constructive features are concerned, it must be a one-man job; and we do not hesitate to say that there are not merely half a dozen but fully a score of civil engineers in America to-day, any one of whom is capable, if left absolutely untrammeled by unnecessary red tape, to take hold of the Panama Canal, enormous undertaking though it be, and pushing it through to completion within a specified time and for a specified cost, and with just as much absence of friction, delay, graft, bickerings, political interference, and all other petty and pure childishness of that kind, as similar works have been and are being carried through by these same men for the various railroads of this country to-day.

A cubic yard of earth, hard pan, or rock is about the same thing at Panama as it is in the Rocky Mountains or on the plains of Dakota. In Panama so many million tons of it can be dug up, blasted out, and carted away, with as much certainty as to cost as it can in the mountains or on the plains of the West. A single Chief Engineer of the Panama Canal, if given an absolutely free hand, can gather around him a staff of engineers just as efficient for their work as any he may have handled when building railroads in a more northern clime. The contractors are ready with their plant and appliances to do just as expeditious work at Panama as in Maine, Missouri or California, and the work they do will be measured up, appraised, and vouched for by the Chief Engineer and his subordinates with just as little "lost motion" and with as great dispatch as in the construction or rebuilding of railroads.

If the unfortunate experience of the government in its initial work on the construction of the canal has no other effect than to teach the above lesson, it will not have been for naught. The course of events suggests that the scheme of administration, as at present adopted, is greatly over-elaborated and is so cumbersome that it will ever be in danger of breaking down of its own weight."

Stated Meeting, held Thursday, December 15, 1904.

Sources of Supply and Methods of Manufacture of Phosphates and Potash Salts.

By Edward B. Voorhees.

Director New Jersey Agriculture Experiment Station, New Brunswick, N.J.

[The author in this article gives a brief account of the various sources of supply of natural phosphates, especially in the United States. Also an account of the well-known Stassfurt deposits of potash salts.—The Editor.]

PHOSPHATES.

Of the mineral elements required by plants, phosphorus and potassium are of the greatest importance. The term "soil exhaustion" means the exhaustion primarily of these constituents rather than any of the other minerals that plants need. In the crops of cereals, hay, flax and cotton grown in this country, there are removed from the soil annually phosphoric acid equivalent to about 7,000,000 tons of super-phosphate, containing 14 per cent. of phosphoric acid, and an equivalent of 2,500,000 tons of muriate of potash containing 50 per cent. of "actual potash." Phosphates useful for the purpose of the manufacture of fertilizers, are obtained from two sources, organic and mineral. Organic phosphates consist chiefly of animal bone—this phosphate has been in use from very early times, though it is within the last century that it has been used in a rational way. The very good results derived from the use of bone, both raw and dissolved, have encouraged its wide use, and often in preference to the phosphates from mineral sources. Mineral phosphates, first discovered in England in 1845, were called "Coprolites." Other deposits have been found since in various parts of Europe and other countries, notably the "Bordeaux Phosphates," in France, "Phosphorites," in Spain, "Apatites," in Norway, "Phosphatic Guanos," in the West and East Indies, and in the islands of the sea, and deposits of greater or less value in Japan and Algeria; in fact, in nearly every country of the globe are found deposits of phosphates useful in the manufacture of fertilizers. Nevertheless, the most abundant and richest deposits are found in America, and

mainly in the United States. The deposits of apatite in Canada, of purely mineral origin, and discovered in 1867, for a time served as a considerable source of supply, but owing to the difficulties in mining, and the expense of separating and handling the phosphates, the output, notwithstanding its high quality, has rapidly declined since 1884. The South Carolina deposits, near Beaufort, S. C., first exploited in 1867, and continuously worked since; the Florida deposits, discovered in 1888, and the extensive Tennessee phosphates, discovered in 1893, have been rapidly developed and are now the chief sources of supply of phosphates of the finest quality. These deposits are not only extensive, but are easy to work, particularly those of Tennessee, and especially well adapted for the manufacture of super-phosphates.

The South Carolina rock phosphate occurs in the form of nodules, ranging from the size of a pea to the size of a man's head, and is found both upon the land and in river beds. On the land, the phosphate-bearing stratas are usually covered with sand to a depth of from six to ten feet, and the stratas vary in thickness from one to several feet. The mining on land is now accomplished by means of steam shovels, which remove the over-burden first, when the phosphate, together with the materials associated with it, is screened and washed, then kiln-dried or burned, in order to remove from it the adhering clay. In the river beds the phosphates are mined by means of a dredge, which scoops up the phosphate, which is then washed and dried, as in the case of the land rock. The composition of the rock varies from 55 to 60 per cent. of bone phosphate, and about 6 per cent. of iron and alumina.

In Florida, the phosphate exists in three forms, namely, rock or boulder phosphate, found in ledges; pebble rock, found in mounds or beaches, and soft phosphate, found in cavities or pockets. These also vary in composition; the boulder frequently reaches as high as 80 per cent. of bone phosphate, and 2½ per cent. of iron and alumina; the soft phosphate contains about 65 per cent. bone phosphate, and 6 of iron and alumina, and the pebble phosphate 62 per cent. bone phosphate, with 3 per cent. iron and alumina. The mining of the Florida phosphate is practically the same as carried out in South Carolina, except that where the over-burden is heavy and there is an

abundance of water, it is removed by means of water—the hydraulic system, therefore, being much more economical of labor.

The Tennessee phosphate does not occur in the form of nodules, but in seams and layers between limestone rocks, and there are three well defined forms, the blue, containing 60 to 70 per cent. bone phosphate, with 2½ per cent. of iron and alumnia; the white, or rose color, containing 82 to 85 per cent. of bone phosphate and very low in iron and alumnia; the brown, ranging from 75 to 80 per cent. of bone phosphate and from 3 to 7 per cent. of iron and alumnia. The mining of the blue and white rock fields is by tunneling, through horizontal entries from the out-crop. The brown rock is entirely open-cut work. The top, or over-burden, is first removed, and then the rock, which lies in layers, is loosened with picks, and handled with forks. The rock when mined is usually sun-dried, or if very dirty, washed and burned.

The various phosphates, both organic and mineral, are in their natural condition insoluble, and thus are not in a condition to quickly supply the needs of plants, nor to meet all the conditions of cropping. Investigations have revealed, however, that for many crops and under many conditions, the organic phosphates, as animal bone and the mineral phosphates, when finely ground, do serve to supply the phosphoric acid rapidly enough to meet all demands. When such is the case, the necessity for further treatment is not apparent, though because these conditions are limited, it is not likely that a very large demand will be made for phosphates in their insoluble form, and the only treatment of which is their fine sub-division. Very early in the history of their use, therefore, studies were made of methods of treatment which would change the insoluble and slowly available phosphates into more quickly available forms, with sulphuric acid, that the reaction resulted in forming a monocalcic, or soluble phosphate, and sulphate of lime. This treated product is the super-phosphate of commerce. At present, therefore, a large portion of the organic phosphates, and practically all of the mineral phosphates are changed into super-phosphates before being applied to the land.

The value of a phosphate from the standpoint of the fertilizer manufacturer, depends both upon its content of phosphate

of lime, as well as its content of iron and alumina. The higher the percentage of iron and alumina, the less valuable, for the manufacturer of super-phosphates, as the presence of these minerals require not only that a larger amount of acid shall be used in the treatment of the phosphate, but the resultant product contains less soluble phosphoric acid, and is more liable to contain a higher percentage of the reverted or the dicalcic form.

The value of a phosphate when used in its natural state, is based upon its content of phosphoric acid, but the value of a phosphate for the manufacture of a super-phosphate depends both upon the amount of phosphoric acid contained in it, and the amount and kind of other constituents associated with it. Phosphates which contain considerable amounts of iron and alumina, are not well adapted for the manufacture of super-phosphates, and no method has yet been perfected which will convert these products into as valuable superphosphates as those derived from phosphates containing minimum amounts of the foreign minerals. Various methods of treatment of phosphates unsuitable for super-phosphates have been used, which, while not making them as valuable under all conditions as super-phosphates, materially increase the availability of the phosphoric acid. Still, these phosphates are better adapted for use as phosphates than as constituent parts of a manufactured fertilizer, of which super-phosphates or acid phosphates now constitute nearly one-half the total weight. A prejudice existed for a long time against super-phosphates, because it was believed that they contained free acid, and would thus injure the land. This has now largely passed away, though this feeling, together with the fact that the continual application of super-phosphates without proper association with other substances does have a tendency to change the physical character, and to some extent the chemical character of the soil, has given rise to the demand for neutral phosphates, those in which there can be no possibility of acid being present. These, however, have not yet been perfected, and the chances are that a broader knowledge of the composition and methods of use of the super-phosphates will rather encourage their use than increase the demand for products of another sort.

POTASH SALTS.

Potash is another constituent that is liable to become exhausted from most soils, though it is not so generally deficient as phosphorous, and is not so liable to be carried away from the farm, because it is contained more largely in the straw than in the grain, and is thus not exported from the farm in the sale of products. It, however, has a wide use, and practically the only source of supply at the present time is the Stassfurt mines, in Germany. These mines were discovered in 1857, and the first factory was established in 1861. There are now twenty-three mines, and the output exceeds 3,500.000 tons annually. This deposit of potash is supposed to have been derived from the evaporation of sea water, hence the deposits in their crude form contain other salts than potassium. These salts are found in well-defined layers from 1,200 to 2,000 feet below the surface. Kainit, containing about 12 per cent. of actual potash, and sylvinit, containing about 16 per cent. of potash, are practically the only crude forms used directly upon the land, or in the manufacture of the mixed fertilizers. The main supply for this purpose consists of the high-grade salts, muriate of potash, which is obtained from carnalite, by boiling with magnesium chloride and concentrating the solution and crystallizing and washing away the impurities. The process generally used in the manufacture of double sulphate and high-grade sulphate is to concentrate a solution of kainit, when, if allowed to stand, the double sulphate of potash and magnesia will crystallize out, forming the double sulphate. The high-grade sulphate of potash and of muriate of potash, which solution when concentrated, and the salt allowed to crystallize, form pure sulphate of potash.

In the manufacture of mixed fertilizers, super-phosphate usually constitutes more than one-half of the total weight of the mixture, while potash is usually contained in much smaller amounts owing largely to the fact of the high content of actual potash contained in the concentrated mixture. The double sulphate contains 26 per cent. of actual potash, the high-grade sulphate and muriate of potash about 50 per cent. actual potash, thus requiring much smaller amounts of these materials to obtain a given percentage.

MAGNETIC NON-IRON ALLOYS.

Prof. J. H. Flemings and R. A. Hadfield in a recent Royal Society paper, give the latest results of their work of investigation of the magnetic qualities of some alloys not containing iron. The alloy experimented with was composed of manganese, 22.42 per cent.; copper, 60.49 per cent.; aluminum, 11.65 per cent.; carbon, 1.5 per cent.; silicon, 0.37 per cent.; iron, 0.21 per cent. About 2 or 3 per cent. of slag was intermingled, mostly consisting of manganese and silicon oxides, with slight traces of metals other than the above mentioned. The conclusions of the paper are as follows:

The above alloy exhibits magnetic properties which are identical with those of a feebly ferro-magnetic material.

The magnetization curve is of the same general form as that of a ferro-magnetic metal, such as cast-iron, and indicates that with a sufficient force a state of magnetic saturation would most probably be attained.

The alloy exhibits the phenomenon of magnetic hysteresis. It requires work to reverse the magnetization of the material and to carry it through a magnetic cycle.

The material has a maximum permeability of 28 to 30, which is not greatly inferior to that of the values reached for cobalt or a low grade of cast-iron for small magnetic forces, and occupies a position intermediate between the permeability of the ferro-magnetic and the merely paramagnetic bodies, such as liquid oxygen and ferric chloride.

The material exhibits, therefore, the phenomenon of magnetic retentivity and coercivity. It is not merely magnetic, but can be permanently magnetized.

A further conclusion is that the magnetic properties of this alloy must be based on a certain similarity of molecular structure with the familiar ferro-magnetic metals. The hypothesis which best fits the facts of ferromagnetism is that materials such as iron, nickel and cobalt, are composed of molecular groups, which are permanently magnetic, and that the process of producing or changing the evident magnetization of a mass of these metals consists in arranging or disturbing the positions of these molecular magnets. Since, then, we have in this alloy an instance of fairly strong ferro-magnetism produced by an admixture of metals possessing in themselves separately no such property, it follows that ferro-magnetism *per se* is not a property of the chemical atom, but of certain molecular groupings. The importance of this fact cannot be easily overstated. It shows us that in spite of the fact that ferro-magnetism has been hitherto regarded as the peculiar characteristic of certain chemical elements—iron, nickel and cobalt—it may, in fact, depend essentially on molecular grouping composed of a comparatively large number of molecules,, and, hence, it may be possible to construct alloys which are as magnetic, or even more magnetic, than iron itself.

Commenting on the paper, our London contemporary, the *Electrician*, says that the discovery of the secret of the molecular grouping referred to would be of immense importance, as it will lay bare the whole mystery of magnetism, and might make possible the manufacture of a material even more magnetic than iron itself.—*Electrical World.*

Mechanical and Engineering Section.

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Superheated Steam in Locomotive Service.

By W. F. M. Goss,

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[The author, in this paper, discusses in an instructive manner, the development and present state of this latest phase of locomotive engineering, giving illustrations of the most promising inventions that have been introduced.—The Editor.

1. *The American Locomotive* has in recent years undergone many changes. Its weight has increased enormously. Extensions of grate to give increased coal-burning capacity have led to changes in the arrangement of wheels. Boilers have been made larger and the pressure carried by them has been raised. Numerous and widely varying experiments have been made in the application of the compound principle, accompanied by an extensive adoption of a single type. Conceptions which at one time were thought to be fundamental have been upset. Whereas designers used to judge the desirability of every detail entering into the construction of a locomotive by its degree of simplicity, the mechanism of the modern locomotive has in the last decade become more and more complicated and the machine as a whole has been made to bristle with fixtures and attachments, no one of which is simple.

These changes have come in response to a demand for higher efficiency or greater power, and the demand in its fullness is not yet satisfied, if indeed it ever can be. In his efforts to keep pace with a growing demand, and at the same time to observe limitations affecting weight, wheel-base and over-all dimensions, which must control in the upbuilding of his proposed machine, the designer neglects no principle which is likely to aid him. Just at present, many different interests are endeavoring to apply in locomotive service the principle

of superheating, the application of which necessitates the use of a considerable amount of apparatus hitherto unknown in locomotive service, and introduces problems which until recently have been regarded as difficult of solution. Nevertheless, so much has already been accomplished and the results are withal of such promise, that the superheating locomotive, while on the lowest round in the ladder of professional favor, has a fine footing and is likely to climb higher. Recognizing this fact, it is my purpose to inquire briefly concerning the principles underlying its action and to reach some conclusion as to the probability of its ultimate success.

2. *Superheated Steam.*—In the process of its generation, steam always has the temperature of the water from which it is produced. What this temperature is, depends entirely upon the pressure to which the water and the steam above it are subjected. Whenever the steam is in the immediate presence of the water from which it is generated, it is said to be saturated. If it becomes mixed with water, it is moist steam. Moisture in steam does not affect its temperature, which is always dependent upon its pressure, the temperature rising or falling as the pressure is increased or diminished. But if steam is removed from the immediate vicinity of the water, from which it was generated, it may be heated to a higher temperature than that of the water from which it is generated, even though its pressure is not increased. It then becomes superheated steam, the extent of the superheating being measured by the difference between its temperature and that of saturated steam of the same pressure.

Superheated steam can never carry moisture. If heat is gradually taken from it, the degree of its superheat is reduced, and finally the superheating disappears. It is then dry and saturated; with any further withdrawal of heat, condensation begins and the mixture becomes part steam and part water. One important difference, then, between superheated steam and saturated steam is to be found in the fact that the former may be made to give up heat without undergoing condensation, whereas any yielding of heat by saturated steam results in condensation. Because of this difference, the behavior of superheated steam in an engine cylinder is quite different from that of saturated steam, with the result that the substitution of

superheated steam for saturated steam is attended by an increased efficiency of an engine. The actual differences in action are complex, but a discussion of them in general terms will not be difficult to follow.

3. *Heat Interchange.*—The average temperature of the metal of an engine cylinder is much lower than the steam in the boiler from which it derives its heat. The reason for this is to be found in the fact that while for one instant it is exposed to the influence of boiler temperature, the next it is exposed to the influence of exhaust temperature. Its exposure is not unlike that of a bar of iron which is alternately thrust into the fire and withdrawn therefrom. Just as a bar thus exposed can never reach the temperature of the fire, so the temperature of the cylinder of a moving engine can never equal that of the steam at initial pressure.

Following now with some care the action which occurs in an engine cylinder, it will be found that there is a constant interchange of heat between the steam and the metal of the cylinder which surrounds it. Dealing first with an engine using saturated steam, and assuming that the piston is at the beginning of its stroke, it is evident that as the saturated steam rushes through the open port, it finds the metal of the cylinder at a comparatively low temperature. The incoming steam must, therefore, give up a portion of its heat to raise the temperature of the surrounding metal. For each unit of heat thus transmitted to the metal, a portion of the saturated steam must be condensed. This condensation continues with the forward movement of the piston until by the time the cut-off is reached, a considerable portion of all the steam admitted exists in the cylinder only as water. While the amount of steam which is thus lost is affected by many things, it may be said in general that under ordinary running conditions, from a quarter to a third of all steam admitted is condensed during admission. The moisture thus formed covers the interior walls of the cylinder just as atmospheric moisture, on a warm day, covers the exterior walls of an ice pitcher. Proceeding with the analysis it will be found that as the piston goes on its course, and expansion begins, the pressure and temperature of the steam gradually fall until a point is finally reached where the steam within the cylinder is no longer hotter than the surrounding

walls. At this point, condensation ceases. Still later, the temperature of the steam falls below that of the walls and the transfer of heat is reversed. The metal of the cylinder now being hotter than the steam and water in the cylinder, a portion of the moisture upon its walls is re-evaporated. This restoration involves but a small per cent. of the initial condensation and it occurs too late in the stroke to be of material service. When the exhaust-port opens, therefore, a very large portion of the initial condensate is still present in the cylinder as water. The metal of the cylinder being now much hotter than the moisture which clings to it, gives up heat rapidly, converting the water into steam which, when generated, passes out of the exhaust-port of the engine. It is important to observe that the heat which is required to evaporate this moisture, resulting from the initial condensation, all comes from the walls of the cylinder. In consequence of this action, the walls are cooled far below their mean temperature, making it necessary for the incoming steam of the next stroke to again heat them, and the whole process must be repeated with each successive stroke of the engine. It will be seen also that by the process described, heat is taken from the steam during admission before it has time to do any considerable work upon the piston. It is restored in part, late in the stroke, but chiefly at a time when the open exhaust valve furnishes a way of immediate escape. It enters the cylinder as steam and leaves it as steam, but during the interval between admission and exhaust, which events mark the effective stroke of the piston, a considerable portion of the whole exists as water. The action of the walls in thus depriving the steam of much of the power it would otherwise have, may be likened unto that of a thermal sponge, which absorbs heat during the effective strokes and gives it out again when its chances for doing work have passed. For the purpose of the present discussion it is important to observe that in this action, the walls are greatly aided by the presence of that moisture which is the vehicle upon which the heat is conveyed away. The problem of producing a highly efficient engine is, in fact, one of reducing the interchange of heat between the steam and the metal of the cylinder, or of adopting a cycle which will serve completely or in part to neutralize its effect.

4. *Methods by which the Interchange may be Reduced.*—A re-

duction in the interchange of heat between the steam and the walls of the cylinder of reciprocating engines may be effected by the adoption of one or more of four different procedures, which may be described as follows:

The first to be mentioned is that which involves a cylinder of non-conducting material. It has been shown that the interchange loss in existing engines is due chiefly to the ease with which the cast-iron of their cylinders receives and gives up heat. If it were possible to find and make practical use of a metal having a lower degree of conductivity, the interchange would be less. But while a great deal of ingenuous work has been done along this line, the construction problems are difficult, and the development of an engine having cylinders of low conductivity, suitable for every-day work, has yet to be accomplished.

A second plan is that of steam-jacketing, in the working out of which, steam is circulated in a space or "jacket" surrounding the working cylinder. The pressure of the jacket steam is equal to or greater than that admitted to the cylinder, and hence the jacket temperature is higher than the average temperature within the cylinder. Its effect, therefore, is to prevent, in some measure, the cooling of the cylinder during exhaust. While its use does not result in the maintenance of a constant temperature in the cylinder walls, it materially reduces the range of change which would otherwise take place. Hence, the exhaust losses are diminished and the initial condensation materially reduced. Steam jackets are much used on stationary and marine engines of the better sort, but have not yet been extensively used in locomotive service.

Another plan for reducing interchange of heat is to be found in the adoption of compound or triple expansion cylinders. By this plan, the desired result is sought by dividing the total range of temperature to which the engine is subjected into two or more stages, and by then assigning a cylinder to each stage. By these means, the difference between the initial and final temperature to which any given cylinder is subjected is reduced. In a compound engine, it is but half that of a single expansion engine, and in a triple expansion engine, but one-third that of a single expansion engine, the initial and final temperature being the same in all cases. As all heat transfer is

proportional to the difference in the temperature of the source of heat and the object heated, such a reduction in the range of temperature to which the walls are exposed results in a material reduction in the initial condensation. With respect to compounding, locomotive builders have made heroic endeavors to keep up with the general progress of steam engine design, with results the full significance of which cannot now be estimated.

A fourth plan for reducing the interchange is that of superheating the steam before admitting it to the engine cylinder. As already pointed out, superheated steam may be made to give up heat without producing condensation. When such steam is admitted to an engine cylinder, the walls which have been left cool by the preceding exhaust are raised in temperature by the heat of its superheat. If the degree of superheating is sufficient, there will be no initial condensation, consequently, as the stroke proceeds, there will be no accumulation of moisture on the walls of the cylinder, and when exhaust occurs, there is no moisture to be vaporized. In the absence of moisture which can act as a vehicle in conveying heat through the exhaust port, the walls are but little cooled during exhaust, and hence require but little initial heating. The accomplishment of the initial heating without the production of moisture reduces the interchange throughout all portions of the cycle. The effect produced by superheating is in fact cumulative.

Summarizing briefly, it may be said that superheated steam, in common with jacketing and compounding, improves the performance of the engine by reducing the interchange of heat between the steam in the cylinder and the metal surrounding it. The precise manner in which this is accomplished is, however, different for each of the three cases. Thus, with superheated steam, the interchange is reduced by the complete or partial elimination of moisture in the cylinder; with jackets the interchange is reduced by a suppression of evaporation during exhaust; and with compound cylinders, it is reduced through a reduction in the range of temperature to which the cylinder walls are exposed. When, therefore, it is announced that a locomotive using superheated steam has given a performance equal to that of a compound locomotive, there is no occasion

for surprise, for the possibility of such a result may easily be demonstrated.

5. *Practical Difficulties in the Use of Superheated Steam.*—As long ago as the early sixties, superheaters were in use upon certain steamers operating on the Atlantic coast. The value of such arrangements were not at all questioned by those concerned with their operation, and elaborate tests by Isherwood served to confirm the popular impression. But the superheaters were difficult to maintain, even though the steam pressure was no more than forty pounds, and notwithstanding the advantage derived from their use, the trouble arising from them led to their gradual abandonment upon the steamers referred to.

In 1877, a series of elaborate tests were conducted by Mr. George B. Dixwell upon a small Harris-Corliss engine when supplied with saturated and superheated steam. These, while confirming previous conclusions as to the advantage of superheated steam, did not at once serve to enlarge American practice in connection therewith. In recent years, while superheaters have occasionally been used in various classes of service, they have gained no footing in our practice, and gradually American engineers have come to believe that the cost of their maintenance quite offsets the advantage to be derived from their use. If, it is argued, the maintenance of the superheater gave trouble when steam pressure was only forty pounds, and the temperature of the superheated steam no more than about 400 degrees F., how much more difficult is the problem to-day when the temperature of saturated steam approaches 400 degrees and that of superheated steam to be effective must be not less than 600 degrees F.? This view is well represented by Professor Peabody in his text-book on "Thermodynamics," which is as follows:

> "Whenever superheated steam has been used so as to give a notable gain in economy, the superheating has been accomplished in a separate apparatus, which has taken the form of a coil of pipe exposed to the products of combustion beyond the boiler. Now, it is the accepted experience of boiler-makers that surfaces exposed to the fire must be of moderate thickness or they will rapidly waste away. Thus, it is not desirable to make furnace-flues more than half an inch thick, and if they are made thicker they are liable to waste away until they are reduced to

> about that thickness. Plates and tubes if thin enough endure long service in a boiler when exposed to the fire because they are kept at a moderate temperature by the water in the boiler. If steam is to be superheated strongly in a coil of pipe or other device which is exposed to hot gases, the metal of the superheater must be strongly heated and is sure to waste away rapidly. There is no material that can stand long service when exposed at once to a high pressure and a high temperature. There is little risk, therefore, in predicting that all superheating devices now used will eventually be discarded for this reason."

While it is true that occasionally during the past twenty years, superheating has been resorted to in connection with stationary plants of unusual significance, enough has been said to show that American engineers threshed out the problem of superheating many years ago, and have since been content to let the matter rest undisturbed. Very recently, however, it has again occupied their attention, and just now it is a subject of more than ordinary interest to locomotive designers. It is but fair to add that this interest has been greatly stimulated by reports from abroad.

6. *Recent Development in the Use of Superheated Steam.*—Abroad, and especially in Germany, for more than a decade there has been a great awakening of interest in superheated steam. The technical schools of Germany have for ten years past been experimenting with large superheaters in connection with their experimental engine plants, and in their practice, as well as in their more scientific work, the Germans have been and are devoting themselves to the problem of superheating. Among those who have had a conspicuous part in this movement, perhaps none have been more energetic or successful than Herr Wilhelm Schmidt. Some ten years ago, Herr Schmidt began the introduction of stationary boilers and engines designed for the generation and use of superheated steam. The Schmidt system as applied to stationary plants involves special construction both in boiler and engine, by means of which a consumption of less than 1.7 pounds of coal per horse power hour has been obtained, while in the case of one plant, the results of which have come under the writer's observation, the consumption was reduced to 1.02 pounds per hour. This is a record of high performance.

The Schmidt stationary boiler has a vertical shell within

which is arranged a large corrugated fire-box and combustion chamber, extending approximately two-thirds the height of the shell. The grate has a smaller area than the cross-section of the fire-box, the difference being effected by a few courses of fire-brick which make up a cylindrical lining for a short distance above the grate. Higher up, the combustion chamber is crossed by circulating tubes of considerable diameter, the surface of which, together with that of the corrugated tube making up the fire-box and combustion chamber, constitutes the direct heating surface. From the top of the combustion chamber, a single flue of considerable diameter opens out through the upper head of the boiler. This flue receives the products of combustion from the fire-box and delivers them to a superheater arranged above the boiler. The superheater consists of pipe 2.4 inches in diameter arranged in a series of flat coils, one above the other, there being as many as twelve coils, while above these superheating coils are other coils forming a feed-water heater.

The action of such a device is apparent. The comparatively small amount of heating surface and the short and direct passage between the furnace and superheater serve to supply the latter with gases at a high temperature, while the extent of superheating surface and the presence of the feed-water heater beyond serve to reduce their temperature to satisfactory limits before they are allowed to escape into the chimney.

Encouraged doubtless by his success in stationary practice, Herr Schmidt has extended the application of his system to locomotives, with the result that from four or five superheating locomotives of a more or less experimental character which were placed in service on the Prussian State Railway, the number has now been increased to more than fifty. It is claimed that the performance of these locomotives is twenty-five per cent. better than that of similar locomotives using saturated steam.

Inspired by German success, American builders and railroad companies have entered upon a period of cautious experimentation. A Canadian railroad, which has been operating one or two superheating locomotives for several years, has recently given orders for a considerable number of such machines. Several of the larger roads of this country are operating one or

more superheating locomotives and the indication is that many more will be forthcoming. For the most part, practice in this country has followed closely the lines of the Schmidt design, though recently certain modifications of this design have appeared.

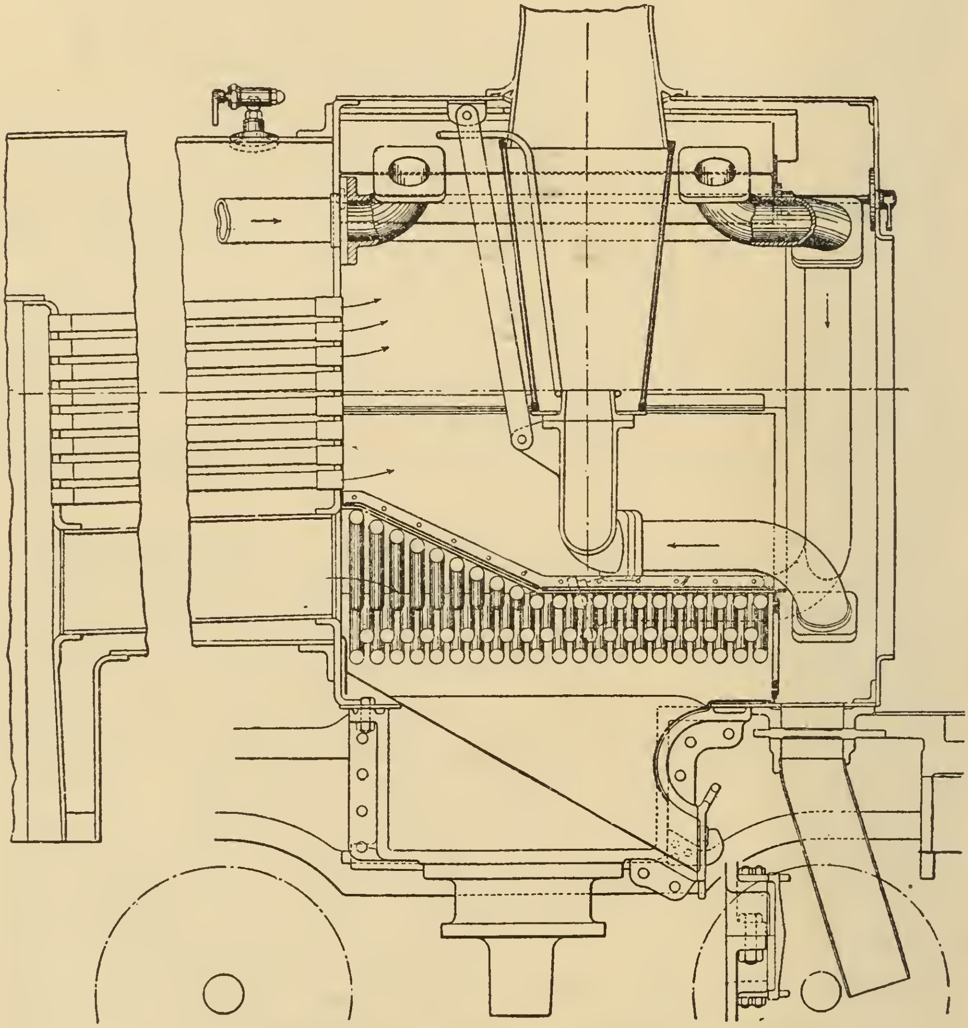

Fig. 1. Longitudinal-section of smokebox with Schmidt superheater.

7 *Locomotive Superheaters.**—The different forms of superheaters which have thus far been placed in service involve no material change in the exterior outline of the locomotive. Their application in all cases leads to some loss in the extent of

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*The writer acknowledges the assistance of Mr. Fritz B. Ernst, Instructor in Car and Locomotive Design, Purdue University, in preparing illustrations and arranging descriptions under this heading.

direct heating surface. Four forms which thus far have attracted public attention may be described as follows:

The Schmidt superheater is shown in longitudinal section by Fig. 1. Its construction involves a flue ten or twelve inches in diameter, extending from the fire-box to the smoke-box

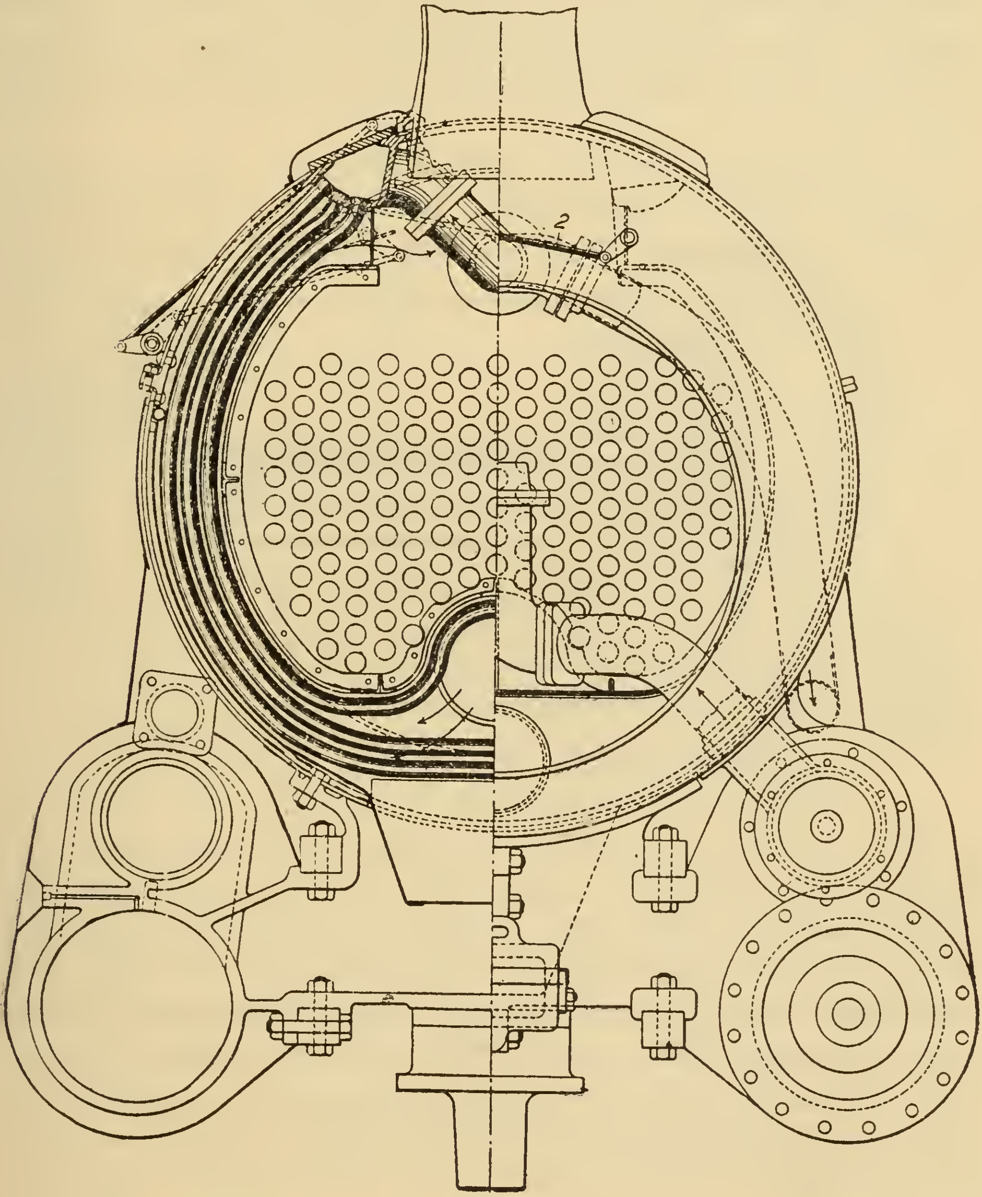


Fig. 2. Cross-section of smokebox with Schmidt superheater.

along the lower portion of the barrel of the boiler. This flue displaces from twenty to thirty of the usual tubes. Its purpose is to deliver to the superheater located in the smoke-box a considerable volume of furnace gases. The large size of the

tube permits the delivery of the gases at a high temperature. The construction is such that while the gases from the smaller tubes of the boiler are free to pass directly up the stack as in the ordinary locomotive, those from the large tube pass into the casing of the superheater within which they circulate around the heating tubes of the superheater, passing upward on either side to points near the base of the stack when they emerge from the superheater and mingle with the gases of the smoke-box.

The superheater has the general form of a horse-shoe, the toe-calk of which is downward. Its form is shown by Fig. 2. It will be seen that its tubes are arranged within a cas-

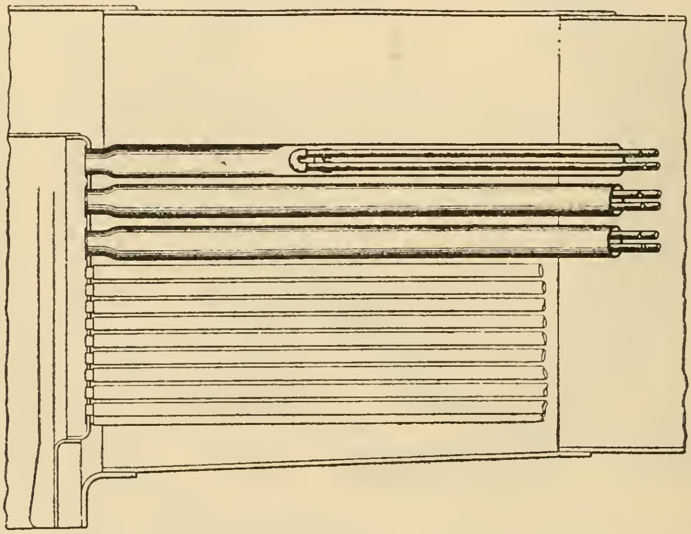
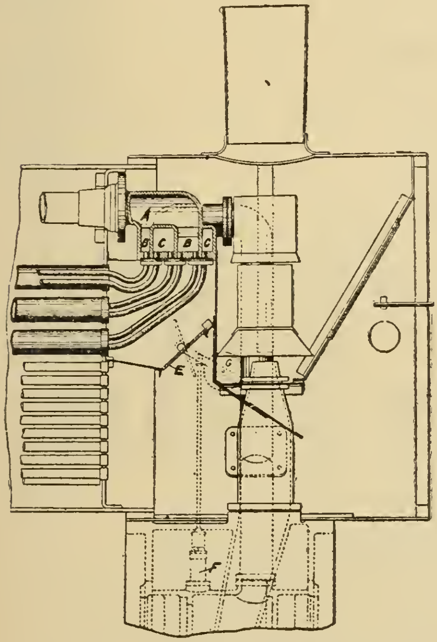


Fig 3. Section of shell showing tubes containing improved Schmidt superheater.

ing between suitable headers. The connections are such that all steam passing the throttle of the locomotive goes to one of the headers, thence by one-half the whole number of tubes around the horse-shoe to the other header, thence by the remaining tubes back to the first header from which it is conveyed to the cylinders. In this passage of the tubes of the superheater, the temperature of the steam is raised to 500 or 600 degrees F., which is from 125 to 225 degrees above the temperature of saturated steam at usual boiler pressure.

The Schmidt improved superheater is shown in part by Fig. 3. In this construction, the nesting of the superheater tubes in the front-end is abandoned for a system of small return tubes arranged within certain of the fire-tubes which are somewhat

enlarged to accommodate them. As is well shown by Fig. 3, the ends of the fire tubes are contracted where they join the fire-box sheet, and the tubes of the superheater are threaded into return fittings. In this construction, the temperature to which the heating tubes are exposed is determined by the nearness they are allowed to approach the fire-box. The connections at the smoke-box end are shown by Fig. 4. Steam from



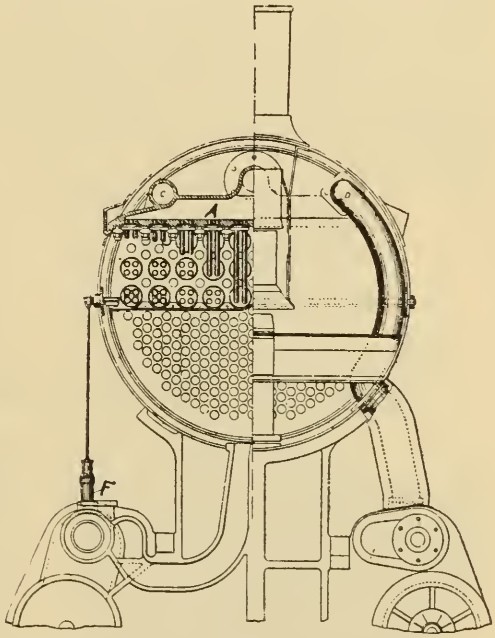


Fig. 4. Longitudinal-section of smokebox with improved Schmidt superheater.
Fig. 5. Cross-section of smokebox with improved Schmidt superheater.

the boiler passes into a large double-chambered header, A, which extends across the smoke-box. From the chambers BB in this box, the steam passes down into one end of the small pipes, thence back to the return bends near the fire-box and back to the compartments C C of the header from which point it is conveyed to the cylinders. A damper, E, serves to control the flow of furnace gases through the superheater. It is so pivoted and weighted that it remains closed except when steam is being used in the engine cylinder, thus protecting the superheater from the action of the fire when no steam is being used. Whenever steam is admitted into the valve box, however, it also enters cylinder F, (Fig. 4), which opens the damper. Fig. 5 shows cross sections of the front-end and makes clear the manner of nesting the superheater tubes in groups of four.

The Pielock superheater (Fig. 6) consists of a box built en-

tirely within the barrel of the boiler and enclosing a certain length of the usual tubes in such a way as to make the enclosed portions of the tubes available as superheating surface. The tubes are lightly rolled into the end plates of the superheater box to exclude the water. It is stated that no trouble is experienced in preventing leakage as the pressure within the box and in the boiler is essentially the same, and the joints need only be made tight against the static head of the water. Moreover, no danger results from such leakage since if the amount is small, the water is evaporated, and if large, it does not disable the locomotive but merely interferes with the action of the superheater. A tube passing from the bottom of the super-

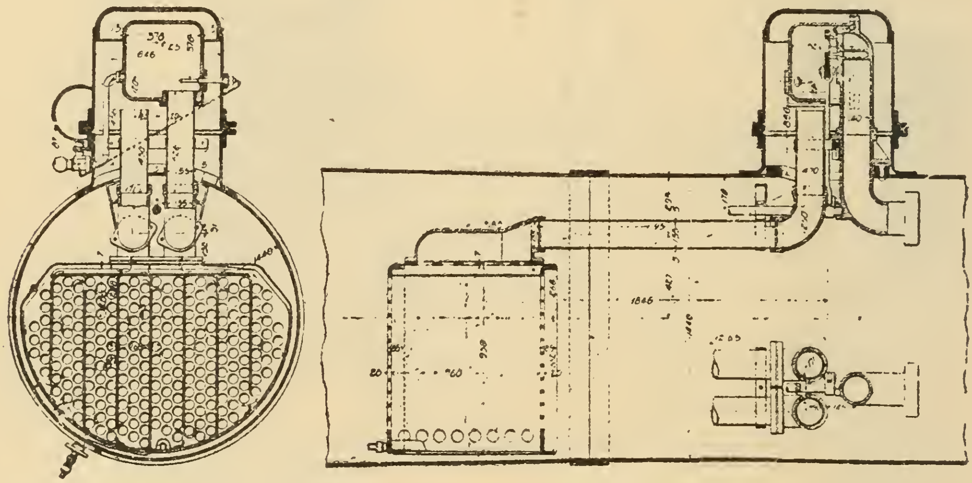


Fig. 6. The Schenectady locomotive superheater.

heater out through the shell of the boiler is fitted with a drain cock, which may be used to ascertain if the superheater is tight. No special fastening of the superheater box is necessary as the box nearly floats and the surplus weight is taken by the large number of tubes to which the box is fastened.

Steam is taken from the dome of the boiler, is conveyed to the heater box where it circulates among the tubes, after which it passes to an enclosed chamber in the dome, thence past the throttle valve to the cylinders. To promote the circulation of steam within the superheater, the box is divided by vertical partitions in several compartments which are joined by openings placed alternately at the top and bottom. These are well shown in the section view of Fig. 6. Two views of a Pielock superheater from photographs are shown by Fig. 7. It is evi-

dent that the degree of superheating may easily be regulated by varying the length of the superheater or its position relative to the fire-box.

It will be of interest to note that the von Borries compound locomotive, exhibited at the Louisiana Purchase Exposition by the Hanover Locomotive Works, and tested by the Pennsylvania Railroad Company, was fitted with a Pielock superheater.

The last form to be described is that of the Cole superheater, which is now being applied in considerable numbers by the American Locomotive Company (Fig. 8). It is, so far as I am

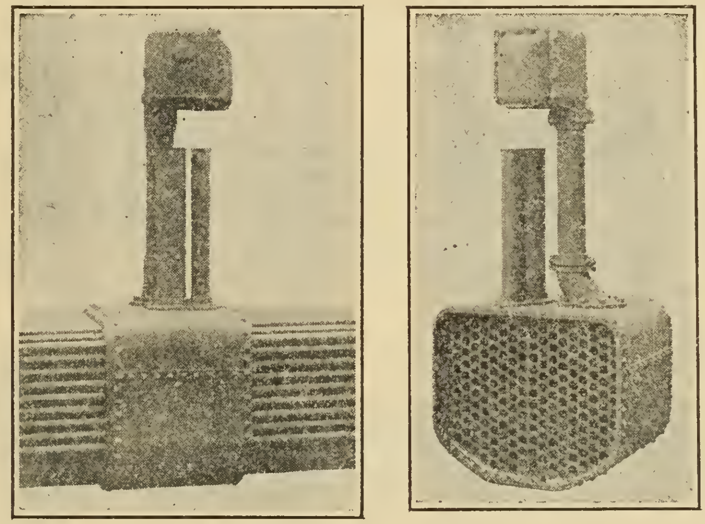


Fig. 7. The Pielock superheater.

informed, the only locomotive superheater which is being projected in this country. It at once suggests the improved Schmidt construction but in its details it is quite different. The fire-tubes in which the heater tubes are placed are of uniform diameter throughout their length, and are but one inch longer than the normal tube. The heater tubes are not looped, but are in single lengths only. There are consequently no joints in the heater pipes. The back end of each heater-tube is closed by welding, the scarfed end being drawn to a form designed to support the heater-tube. The end of the heater-tube is not in the center of the fire-tube but is raised to the top of the latter, thus increasing the area of the clear space below and lessening the chance of

the tubes becoming stopped by lumps of fuel. The smoke-box end of the heater-tube is straight. Connections for the circulation of steam are as follows:

Steam from the throttle is delivered into the upper compartment of a T-shaped head, which extends nearly across the width of the smoke-box. The lower compartment of this fitting is in pipe connection with the cylinders. To the front side of the T-shaped head are attached a number of cast headers, the joint being made with a copper gasket as in steam-chest practice. Each header is sub-divided by a vertical partition into a forward and back compartment. Through holes in the front wall and the partition wall of the headers, the tubes of the superheater, $1\frac{3}{4}$ inches in diameter, are inserted and pushed

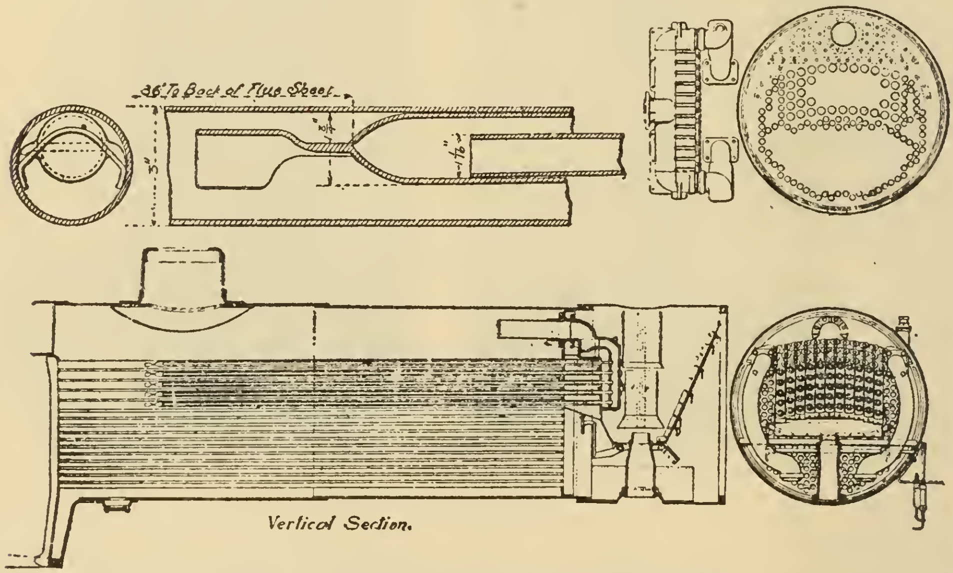


Fig. 8. The Schenectady locomotive superheater.

back into the fire-tube, the forward end being expanded into the back wall of the header. Next, the circulating tubes, $1\frac{1}{16}$ inches in diameter, the forward ends of which are expanded into special plugs, are inserted within the heater-tubes and the plugs screwed to place in the vertical partition wall of the header. The openings in the forward wall of the headers are then closed by plugs. In action, steam passing the throttle, finds its way to the forward compartment of the headers, thence through the circulating tubes to the back end of the superheater tubes, thence through the superheater tubes to the back compartment of the headers, and thence by branch pipes

on to the cylinders. A damper arrangement similar to that employed in the Schmidt superheater is used to protect the heater-tubes from excessive heat when steam is not being passed through them.

8. *Concerning the Probable Success of Superheating in Locomotive Service.*—The prediction of Professor Peabody, already quoted, to the effect that all superheating devices will in the end be discarded, has doubtless been generally accepted by the rank and file of American engineers. For them the problem has had no mysteries. They have understood the thermodynamics of the problem. They have admitted that the use of superheated steam in engines is always attended by a more efficient cylinder action, but past experience has taught them that the difficulties in maintaining a superheater were too great to justify its continued use. They have argued that since this was true thirty years ago when steam pressures were so low that the temperature of the superheated steam was less than that of saturated steam of to-day, the problem of superheating is now vastly more difficult than it has ever been before. The prevalence of this view in this country naturally leads many to question whether even Germany's great progress and the more recent but equally promising start of the American Locomotive Company are as yet sufficient to insure a future for the practice. In raising this question it is not intended to minimize the value of the elaborate researches of Schmidt, Schroter and other German investigators, or of the equally valuable experience which has been gained in the application of principles. The endeavor has been made to make the fact clear that between apparently most promising and even masterful experimentation and an assured success in practice, a broad gulf is fixed, and that the voyage across is not yet finished.

Turning now from convictions based on previous experience, and approaching the subject without prejudice, it is well, first of all, to recognize the fact that when a principle in operation is correct and when it is generally understood, it is never safe to assume that the means whereby it may be utilized will forever fail to be forthcoming. The reverse is likely to be true. The efforts to use superheated steam in the cylinder of an engine are based upon correct thermodynamic principles, and hence, sooner or later, practice will embrace it. Again, it goes with-

out saying, that with the better materials and larger experience of to-day, the problem of producing and utilizing superheated steam can be approached with greater certainty than was possible in the practice of many years ago. Proof of this is to be seen in the degree of success already achieved.

Examining the question broadly, we shall find that locomotive service is more favorable to the use of the superheater than any other in which it has been tried. The installations with which we have hitherto dealt have served in stationary or marine practice. The superheater of these plants has either been a separate boiler-like device, in which no water was carried, or has been so combined with the boiler as to always be in close communication with its furnace. Under these conditions, when the engine throttle is closed, the circulation of steam within the superheater tubes ceases and the metal of the tubes, together with the entrapped steam within them, remain exposed to the undiminished intensity of the furnace action. In this manner, the tubes are often heated to very high temperatures, a result which when frequently repeated leads necessarily to a failure of the superheater. Again, when after an interval of inactivity, the engine is started, the steam which has been held back within the superheater until it has been raised to an enormously high temperature, passes on to the engine, often times retaining enough of its heat to burn the lubrication and sometimes to destroy the rod packings. But all difficulties of this class which to a greater or lesser degree have appeared in the operation of every stationary engine plant using superheated steam, are doubtless avoided in the locomotive, for in this machine, the rate of combustion varies with the volume of steam used. When the throttle is open, the fire burns brightly; when it is closed, its activity is at once suppressed. When there is no steam passing within the tubes of the superheater, the gases circulating around the tubes are comparatively low in temperature, and when the conditions are so changed that the temperature of the gases becomes maximum, the volume of steam passing the tubes is greatest. Just as the draft of a locomotive responds to the varying demands which are made upon the boiler, so the volume of heat which is available for superheating varies with the quantity of steam which is to be superheated. The details of several of the designs described provide

that when the blower is on, dampers are closed, which prevent the circulation of gases in the superheater, so that it is only when the throttle is open that the superheater does work. While it is my opinion that the automatic damper is in fact unnecessary, it is certainly true that with it, overheating of the superheater becomes impossible. In view of the highly favorable character of all these conditions, it is likely that it will be found easier to maintain a superheater on a locomotive than in connection with any other type of engine, and, moreover, that superheating in locomotive service may be a pronounced success, while in other classes of service, its future may still be problematical.

9. *Efficiency and Power.*—It may be accepted as beyond question that the use of superheated steam will materially improve the efficiency of the locomotive. The saving resulting from its use is a two-fold one. For the development of a given power, the cylinders of the superheating locomotive require less steam, and as the demand for steam diminishes, the efficiency of the boiler increases, so that there is not only a saving in steam but a proportionately greater saving in coal. The German claim that 25 per cent. of the coal burned is saved by the use of superheated steam is as a general statement probably extravagant, but it is not so high as to be impossible.

Again, while economy in the use of fuel is of great importance, it is in many classes of service secondary to questions affecting the output of power. Modern conditions impose many restrictions and limitations as to the weight and dimensions of a locomotive, while at the same time they call for the development of greater power. It is, therefore, important to note that in locomotive service anything which improves the efficiency of the machine, may be utilized to extend its limit of power. The power delivered per unit weight of coal burned and also the power delivered per unit weight of locomotive, is increased by the use of superheated steam. It appears, therefore, that one way in which the power of locomotives may be increased is to equip them for superheated steam.

Obviously, it should not be claimed that full advantage is to be had of the increase of economy and of power at the same instant. One effect is always sacrificed for the other. Under ordinary conditions of running, full advantage is derived from

the improved economy while in an emergency when the locomotive must be worked at its maximum power, then at a temporary sacrifice of efficiency, limit of power may be raised.

10. *Incidental Considerations.*—A fact of interest which should appear in the use of superheated steam is a decided improvement in steam distribution which indeed may constitute a factor in the resulting economy. With superheated steam, the initial condensation is suppressed and the ports are required to pass only that steam which is effective in doing work, whereas with saturated steam they must pass in addition to this, that which is represented by the initial condensation. Assuming port areas to be the same, those for a superheating locomotive are in effect from 20 to 25 per cent. more liberal than for a locomotive using saturated steam. In high speed service, this becomes a matter of consequence.

An objection frequently raised against the use of superheated steam is to the effect that it increases the difficulty in cylinder lubrication. Troubles of this kind have in fact been common enough in stationary practice, but the fact should not be lost sight of that they have followed a period when for some reason the superheater has been overheated. Under normal conditions, an engine supplied with superheated steam has saturated steam in its cylinders, and the maximum temperature of the cylinder walls is not higher than when saturated steam is used. It has already been shown that there is little danger of overheating a locomotive superheater and consequently difficulties with lubrication are not to be found.

11. *In Conclusion,* to briefly summarize preceding statements, it appears that from an academic point of view, the conditions of locomotive service are very favorable to the use of superheated steam; that its use makes possible a better distribution of steam, it greatly improves the economic performance of the locomotive and increases the capacity of the locomotive for doing work; that the maintenance of the superheater is not likely to prove serious nor is any trouble to be expected in securing satisfactory cylinder lubrication; that the adoption of superheated steam in locomotive service can probably be accomplished without greater difficulty than that which attends the introduction of any other important detail entering into loco-

motive construction; and that substantial progress has already been made in the application of the principles involved.

ENGINEERING LABORATORY, PURDUE UNIVERSITY,
MARCH 1, 1905. LAFAYETTE, IND.

DISCUSSION.

MR. M. N. FORNEY.—The subject of superheating of steam is one that has been discussed for a long time. In Rankine's book on the Steam Engine, written nearly fifty years ago, there is a demonstration showing the economies which may be attained by superheating, and since then it has often been tried, and such trials have shown that a very important saving in fuel can be effected thereby. When Rankine wrote his book only animal oils were used for lubrication, and vegetable fiber for piston and valve-rod packing. Neither of them would stand a high temperature, and consequently when that of the steam used was materially increased, the oil and hemp packing were destroyed by the increased heat. As a consequence the cylinders, packing and piston-rods were abraded and injured. Away back in the fifties, when Mr. Henry Tyson was master of machinery on the Baltimore & Ohio Railroad, he had some of the upper row of tubes in a locomotive boiler bent upward, so that the curved portion projected into the steam space above the water. This had the effect of heating the steam more or less, but when it was tried, the cylinders were quickly abraded and ruined, so that the experiment was abandoned. The introduction of mineral oil, which will withstand a much higher temperature than animal oil, and of metallic piston-rod packing, makes the use of superheated steam practicable now, when formerly it was not, and during the past decade or two, we find that renewed attention has been given to the subject and some very remarkable economies are reported as the result of its use in stationary, marine and locomotive engines, and the advantage in the latter has now been distinctly recognized.

But in the adoption of any improvements in locomotives the fact must be recognized that it is often easier to save coal than it is to save money. In other words, the cost of the devices for effecting the economy and the expense of maintaining may amount to more than that of the fuel saved.

There is another consideration, which should never be lost sight of. That is that the prime purpose of locomotives is to haul cars on railroads, and that anything which interferes with this in any way, by getting out of order, which lessens the amount of service which a locomotive will perform, is quite certain to be abandoned. A locomotive on a railroad occupies a relation to it which a reaping machine does to a farm. The prominent purpose of such a machine is to cut the grain when the harvest is ripe. Now, any device, no matter how useful, which will interfere with this purpose, at the critical period of harvest, etc., is quite sure to be condemned and its use abandoned. On a railroad, the delay of trains, especially with the line is crowded with traffic, interferes very seriously with the business of the road, and this becomes costly. Therefore any so-called improvement in locomotives which will lessen the amount of work which they can do in a week or month or a year, is quite sure to fall into disuse. Superheating, like every other improvement, will be subjected to this test and if it is found after full trial that locomotives with superheaters will do more work and with less fuel than they will without, they will be generally adopted, otherwise, it is quite safe to predict they will not be. To save fuel alone is not a sufficient advantage to secure their general use. They must do this without materially increasing the other expenses or diminishing the amount of work the locomotive will do.

It is not the purpose of these remarks to throw cold water on superheating. At present the results therefrom which have been reported, look very promising, and indicate that greater economy may be attained therefrom than from any other improvements in locomotives which are now proposed, but in making out a balance sheet, it is essential to give as much attention to the debit as to the credit side.

GASOLINE MOTOR AS AN AUXILIARY TO SAILS.

An interesting application of gasoline motor for marine purposes was recently demonstrated upon the arrival in the Thames of the auxiliary vessel "Sirra," of 500 tons, from Dordrecht. This vessel is a three-masted schooner, and with the large area of sails provided in a fast boat on the high seas. The craft, however, is also intended for service upon canals, for which purpose the masts are hinged, thereby enabling them to be low-

ered for passage beneath bridges. When the sails are unavailable the boat is propelled by a gasoline motor. There is a small single propeller placed well below the water line. The motor is placed right aft so as to reduce the length of shafting as much as possible, and is controlled from the poop by means of a hand wheel and lever. The provision of this auxiliary power was strongly emphasized upon the arrival of the vessel in the Thames. Instead of waiting for the tide, or requisitioning a tug, the vessel was driven up by the gasoline motor at a steady speed of six knots, and as the masts were lowered could pass beneath the bridges easily. Such a combination of wind and motor power presents many possibilities, since a vessel so equipped has great economy in power, ease in working, and adaptability to circumstances. The "Sirra" was visited by many marine engineers interested in the problem of river navigation during her stay in the Thames. It afforded a concrete example of how the question of dealing with canal traffic may be efficiently and economically handled. Such a system is much cheaper than electrical towage both from point of initial expense and maintenance, and far more expeditious than animal traction for canals and similar waterways.—*Scientific American.*

Book Notices.

Report of the U. S. Naval Fuel Board, of tests conducted on the Hohenstein water tube boiler, showing the relative evaporative efficiency of coal and liquid fuel under forced and natural draft, as determined by an extended series of tests made by direction of the Bureau of Steam Engineering, Navy Department, Washington, D. C. Washington: Government Printing Office. 1904.

In Rear Admiral Melville's Report of 1902 allusion is made to the great importance of a correct solution of the naval boiler problem, and he points out the necessity of providing a type of water-tube boilers for the navy, of American design, and of such simple construction that ordinary firemen can take care of them without danger of damage or failure. The Oil City Boiler Works offered to build and install a boiler of the Hohenstein type, and subject the same to any test which the Navy Department might wish to make This offer was accepted, the boiler was installed at the Washington Navy Yard, and a board, consisting of Commander John R. Edwards, Lieut. Commander W. M. Parks and Lieut. Commander F. H. Bailey, was appointed to make the tests.

The boiler was enclosed in a steel house, fitted with air-lock entrance, to adapt it for forced draft, and containing a blower, air compressor, several pumps, scales, gauges, feed tanks, etc., and a set of seventeen tests were made of respectively three, four, six and eight hours' duration, alternately with natural and forced draft, burning coal. The results are grouped in several tables, and finally combined in a very interesting summary, from which we will only quote the following results:

EQUIVALENT EVAPORATION FROM AND AT 212 DEGREES PER POUND OF DRY COAL.

Forced draft	8.28 ℔s.
Natural draft	10.28 "

COAL PER SQUARE FEET OF GRATE PER HOUR.

Forced draft	47.8 lbs.
Natural draft	21.3 "

After the completion of the coal tests, the boiler and appliances were arranged for oil tests, proper burners were put in the furnace, air compressors and oil tanks provided, and the oil fuel was injected by steam, compressed air, or both combined. All the appliances are fully described and illustrated in detail, also a number of burners of different types. Seventy-nine different tests were then made under varying conditions as to draft, burners, mode of injection, etc., and the results are compiled in tables, and finally combined in a summary, from which we quote as follows:

EQUIVALENT EVAPORATION FROM AND AT 212 DEGREES PER POUND OF OIL.

Forced draft	10.19 lbs.
Natural draft	14.43 "

OIL PER SQUARE FEET OF GRATE.

Forced draft	45.97 lbs.
Natural draft	15.25 "

As a supplement to these tests the installation of oil fuel burners and results of same of the following vessels are described and illustrated: Steamers "Nevadan" and "Nebraskan," of the Hawaiian-American Company, made by the New York S. B. Company, Camden, N. J.; steamers "Mariposa" and "Alameda," Oceanic S.S. Company, made by Risdon Iron Works, San Francisco.

Tests and voyages on the latter were reported to the U. S. Navy Department by Captain Stevenson, U.S.N., and Lieut. Commander Winchell, U.S.N.

Installations for locomotives and torpedo boats, tests on the Italian steamer "Tebe," installation on S.S. "City of Everett," of the Standard Oil Company, are also fully described, and the book closes with articles on relative prices of oil, storage on board vessels, and a general resumé on economical advantages, military considerations, etc., of liquid fuel application.

The U. S. Navy Department is entitled to the thanks of the public, and particularly of those interested in transportation, shipbuilding and manufacturing generally, for undertaking these costly experiments, and the Bureau of Steam Engineering, together with the very able board in charge of these tests, must be complimented on the careful, skilful and painstaking labor performed in making these tests and compiling their results. J. H.

Leçons sur L'Electricité professées à l'Institute Electrotechnique Montefiore, Par Eric Gerard. Directeur de cet Institut. Septième Edition, entiérement refondue. Deux volumes grand in-8 (25x16). Tome second, pp. viii+888. Gauthier-Villars. 1905. (Price, 12 fcs.)

Several previous editions of this very thorough treatise have been noticed from time to time in the *Journal*. The best evidence of its value is afforded by the announcement of the appearance of the seventh edition.

This volume treats of transformers, the distribution of electric energy; applications of electricity to telegraphy, telephony, lighting, to the generation and transmission of power, to traction, to metallurgy, and to the chemical industry. W.

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Stated Meeting, held Wednesday, March 15, 1905.

The Telautograph.

BY H. I. ENGLISH.

[This paper includes a brief account of the invention and development of the Gray telautograph, and deals specially with the instrument in its present commercial form.—THE EDITOR.]

Electrical transmission of handwriting has engaged a certain amount of attention ever since telegraphic transmission or printed characters was successfully carried out.

As early as 1886 Cowper and Robertson brought the writing telegraph into a fairly operative form. This instrument was adapted to operate several receivers in series in "reporting" service, where the regular news ticker service was unobtainable or too expensive. The system was put to some use, chiefly in Pittsburgh and vicinity.

The writing was received on a paper tape, advanced at constant speed by clockwork. No pen-lifting device was provided

and the words were connected together by a mark of the pen, making figurework poor. As the characters were formed by the combination of the pen motion and the tape motion, a certain amount of practice and skill was required to produce a legible message.

The electrical features were as follows: Two independent variable currents were obtained from the transmitter; these passed over lines to the receiver where they traversed two electromagnets set at right angles to each other, and so influenced their effect upon a common armature as to cause the receiver-pen rod to produce the motion of the transmitter pencil.

It will be noted that this principle is nearly identical with that of Gruhn's Telechirograph, recently described in the technical press, the main differences being that the telechirograph writes upon a larger field and uses a beam of light, and photographic record instead of a pen with ink record.

Following the writing telegraph, Professor Elisha Gray constructed, at his Chicago laboratory, an instrument which wrote upon stationary paper, and which he called a telautograph. It required four line wires and operated as follows: By means of cords and drums the motions of the transmitting stylus were resolved into two mechanical interrupters in the primary circuits of two induction coils. The relations of the parts were such that a motion of the transmitting stylus amounting to one-fortieth of an inch caused a complete make-and-break at one or both of the interrupters.

The line currents were the impulses produced in the secondary circuits of the induction coils. These impulses passed over lines to two electromechanical escapements in the receiver. By means of cords and drums their motions were combined and caused to act upon the receiver pen. By the use of relays and condensers and a local battery at each receiver the paper was advanced when necessary and the pen lifted from and lowered to the paper. The mechanical difficulties met with in perfecting this instrument were very great, and in the apparatus exhibited at the World's Fair, in Chicago, in 1893, the escapement mechanism was brought to a perfection thought impossible of attainment only a short time before. The writing showed a saw-tooth or step-by-step character, due to the action of the escapements. The instrument was aband-

oned on account of the number of line wires required, limited speed, numerous fine adjustments, and cost and difficulty of manufacture.

In 1893, while still working at the escapement device, Professor Gray patented a variable-current instrument, using two line wires, which worked, in a general way, like the present telautograph. The motions of the transmitter pencil were resolved into two components which were used to vary two line currents, the variable resistances being carbon rods dipped into tubes of mercury. The receiver contained two D'Arsonval movements, to the moving elements of which the pen-arms were attached. Professor Gray never developed this instrument much beyond the laboratory stage, probably on account of his firm belief in the escapement type.

Foster Ritchie, at that time an assistant to Professor Gray, gave considerable attention to this patent and perfected an instrument based on it. He obtained a patent for improvements and has produced an instrument that operates in a fairly satisfactory manner under certain favorable conditions.

The telautograph has been brought to its present state chiefly through experimental work done by, or under the personal direction of Mr. George S. Tiffany, to whom several patents for improvements have been granted. Mr. Tiffany's instrument operates on the variable-current principle and includes a number of interesting features, among them what may be called a straight-line D'Arsonval movement, which is used to operate the receiver.

The operation may be briefly described thus: At the transmitter a pencil is attached by rods to two lever-arms which carry contact-rollers at their ends. These rollers bear against the surface of two current-carrying rheostats, connected to a constant-pressure source of direct current. The writing currents pass from the rheostats to the rollers and from them to the line wires. When the pencil is moved, as in writing, the positions of the rollers upon the rheostats are changed and currents of varying strength go out upon the line wires. At the receiver these currents pass through two vertically movable coils, suspended by springs in magnetic fields, and the coils move up or down according to the strength of the line surrents. The motions of the coils are communicated to levers similar to

those at the transmitter, and on these levers is mounted the receiver pen, which, by the motion of the coils, is caused to duplicate the motions of the sending pencil.

Many of the principles and devices in the instruments are of considerable interest. The method by which the variable currents are obtained is the laboratory arrangement for securing a variable pressure from a direct current, constant pressure circuit; that is, the line circuit (of constant resistance) is connected as a shunt around that part of the rheostat between the moving roller and the ground or return. Motion of the roller varies the amount of resistance in series with the line and also the amount in parallel with it and fine graduations are easily obtained, giving smooth motion of the receiver pen. In this way a variable pressure is impressed on the line circuit, giving a variable current. In all the other variable-current instruments, a constant pressure was impressed on line and a resistance in series with the line varied to give the desired variations in current. One result of the shunting method is a better form of rheostat, more easy of construction and handling, in which, also, the heating is better distributed.

The rheostats are wound upon castings of I cross-section, with the turns of wire lying close together on the inner or contact-face. After winding, the insulation on this face is saturated with glue, which is allowed to harden and is then scraped off, taking the insulation with it, and giving a surface where contact is possible on every turn of the wire. This gives a rheostat of a large number of small steps, of good mechanical construction, and of low cost.

The receiver operates with what may be called a straight-line D'Arsonval movement. The moving element or coil is wound upon a copper shell for damping effect. The magnetic circuit is so arranged that one pole surrounds the other, forming an annular air-gap of short length and large cross-section in which the direction of the flux is radial. The field is electromagnetic and is highly excited, to secure uniformity. The coil suspended in the annular space, moves up or down with little friction, as it touches the sides of the space of the core very lightly, if at all. The principle is the well-known one that a circuit-carrying coil, in a magnetic field, tends to place itself

with respect to the field so that the flux enclosed by the coil shall be a maximum.

The current for operating is taken from the ordinary lighting mains, preferably at about 115 volts. Satisfactory operation has resulted with pressures from 80 up to 250. At 115 volts, receiver and transmitter each require about one ampere while in operation. Fairly steady pressure is necessary as the receiver, being in effect a voltmeter, is rather sensitive to sudden changes, the effect being slight distortion of the message.

A master-switch at the transmitter is provided to do all necessary switching of line and power circuits, to make needed changes in connections and to cut off current when not writing. A relay in one of the lines closes the power circuit of the receiver whenever the transmitter at the distant station is switched on, and serves to prevent waste of current when not in operation.

Attached to the master-switch is a mechanical device which shifts the transmitter paper the space of one line of ordinary writing for each stroke of the switch. The relay mentioned controls the electrical receiver paper shifter and, as each stroke of the switch causes a stroke of the relay, the receiver paper is shifted an amount equal to that at the transmitter. The writing is about two inches long and five inches wide, allowing for three or four lines of writing. When filled by messages a few strokes of the switch serve to bring fresh paper into position at both receiver and transmitter.

To prevent switching on of the transmitter while its home receiver is receiving a message from the distant station, an electromagnetic lock is connected in the receiver power circuit, controlled by the relay, and locks the home transmitter in the "off" position until the distant transmitter is switched off. If both transmitters were switched on at once neither station would receive any message; the lock is provided to render this condition impossible.

The ink supply is most important and is arranged for as follows: At the left of the receiver platen is a bottle with a hole in the front near the bottom. When filled with ink and tightly corked the ink does not run out of this hole because of the pressure of the atmosphere. The ink is accessible for the pen

at the hole and the surface of ink exposed to evaporation is small.

The pen is made of a piece of German silver bent double, after the manner of a ruling pen, and makes a uniform line in any direction over the paper. It takes up its supply by capillary attraction, from the hole in the front of the bottle. When the receiver is switched off, retractile springs draw the pen-arms to stops so arranged as to bring the pen exactly in front of the hole in the bottle, and when the pen-lifter armature is released the pen is caused to insert its tip in the opening. Thus a fresh filling of ink is obtained each time the paper is shifted. When not in use the pen rests in the ink, always ready to write.

For the prevention of mechanical shocks to the necessarily light moving system of the receiver, it has been necessary to supply means to prevent the switching on or off of the transmitter, and by that action of the receiver, when the transmitter pencil is "out in the field;" that is, at a position other than that corresponding to the opening in the receiver ink-bottle; as in that case the receiver pen would instantly jump to a similar position. This position is called the "unison point," a term having its origin in the days of the "self-propellor" escapement telautograph. By placing a catch, released only by pressure of the pencil-point upon it, at the transmitter unison point the desired result is accomplished and the transmitter master-switch cannot be switched either "off" or "on" unless the pencil be placed at the unison point and held there until the stroke of the switch is completed. In this case, as everywhere, the apparatus is made strong enough to stand any possible shocks, and then every precaution is taken to prevent their occurrence. Aside from shock to the moving system, these jumps might shake the ink supply out of the pen and prevent the recording of the message.

The pen-lifter is a magnet placed back of the receiver writing platen, and carrying upon its armature a rod adapted to engage with the pen-arm rods and raise the pen clear of the paper when the magnet is energized. This magnet is controlled from the transmitter as follows: Beneath the transmitter platen is a spring contact, opened by pressure of the pencil upon the paper, and closed by a spring when the pencil is raised. An induction coil having an interrupter in its primary circuit is so

connected to this spring-contact that when the pencil is raised the primary winding is short circuited. The induction coil has two independent secondary windings through which the two variable line currents pass before leaving the transmitter. The effect of the induction coil and its interrupted primary current is to induce in the two-line current superimposed vibrations or "ripples" when the pencil is pressed down on the paper and the spring-contact is open. When the contact is closed, by its spring, and the primary winding is cut out, no vibrations are produced in the line currents. In one of the line wires, at the receiver, is placed a relay, upon whose sheet-iron diaphragm armature is mounted a loose contact, consisting of two platinum-silver contacts in series, sealed in a glass tube, to prevent oxidation. A local circuit contains the winding of the pen-lifter magnet and this loose contact.

When the vibrations are present in the line current, due to the pressure of the pencil upon the paper and consequent opening of short circuit of the primary of the induction coil, the diaphragm of the relay is shaken, the loose contact opened and the pen-lifter de-energized, its armature is drawn back by a spring and the pen is allowed to rest against the paper. When there are no vibrations in the line currents due to the raising of the pencil from the paper, the relay diaphragm is at rest and the pen-lifter is energized and the pen is lifted clear of the paper.

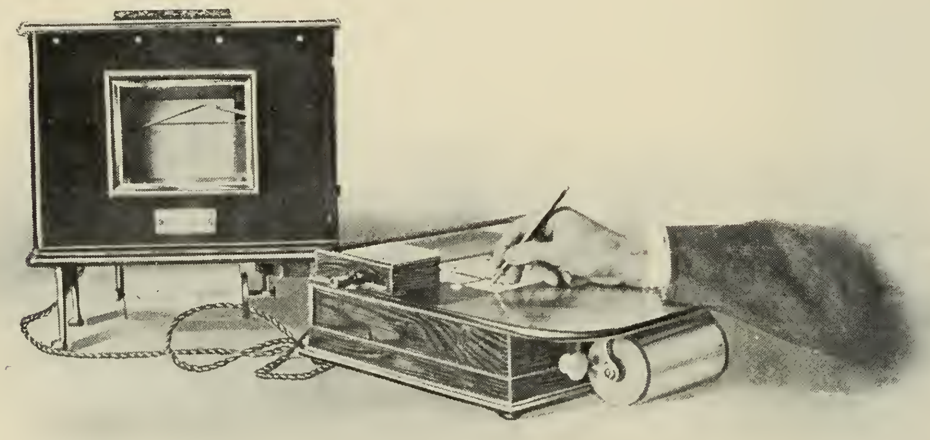
The superimposed vibrations used for operating the pen-lifter have another minor effect. The suspended coils, and through them the entire moving system of the receiver, are kept in a state of very slight mechanical vibration while the pen is on the paper. This aids the flow of ink from the pen-point, assists the pen in passing over any roughness or irregularity in the surface of the paper, and materially reduces friction in the joints and pivots of the moving system, and results in better writing. In some of the later instruments the two relays, that for pen-lifting and that for paper-shifting and power switching, are combined in a single piece of apparatus.

For signalling, a push-button is placed upon the transmitter and a call-bell or buzzer is mounted on the receiver. This circuit is disconnected by the master-switch while a message is being written. Spring reels are attached when needed to roll

up the received messages for preservation and future reference.

The ordinary arrangements for operation are as follows: The instruments may be operated singly, upon a private line having an instrument at each end, or on an exchange system where a switchboard provides for connection. Working in this way, satisfactory writing has been obtained with a resistance in each line wire of 1600 ohms and an operating pressure of 110. Multiple operation can be carried out to a limited extent, three receivers being at present the maximum number that can be operated at once, in multiple, using 110 volts. This allows of placing a supervisory machine upon a line.

Instances in actual commercial use of the arrangements of instruments in Philadelphia are: Provident Life and Trust Co., Corn Exchange National Bank, West End Trust, Tradesmen's



Trust Co., Girard Trust Co., who use the Telautograph to connect from paying teller to book-keeper to ascertain a depositor's balance. C. J. Webb & Co., 116 Chestnut Street, have a line which connects to their warehouse, 148 N. Front Street, for giving orders for shipment of wool. Philadelphia Electric Co. have a line to connect from 10th and Sansom to Second and Arch Streets; this line is used mainly for sending the readings of meters to the book-keeping department.

Strawbridge & Clothier use the instrument to connect from the Superintendent's office to the Auditing Department, for ascertaining a customer's credit. Finley Acker Co. have lines

which connect their three stores, Twelfth and Chestnut, Twelfth and Market and 128 N. Eighth Street, to their book-keeping department, to ascertain the reliability of a customer's credit.

Multiple operation may be resorted to when a third station upon a line desires a record accessible at any time, of what is being sent, as for instance, when one of the officers of a bank desires to know what passes between his book-keepers and paying tellers. On such a line the third station receives all messages and can write to either or both of the other stations should the necessity arise. Such an installation can be seen at the North American Trust Co., New York.

Series operations may be used when several stations are to receive the same message and no response except a bell signal is required, as in sending orders in a hotel or club from dining room to kitchen, pantry, or wine room; in "reporting" or news service, or for bulletin work, such as the announcement of arrival and departure of trains to a number of stations in a large railway station or freight depot.

Recently two such installations, one at the St. Louis Terminal, St. Louis, Mo., the other at the Pittsburgh Terminal of the Pennsylvania Railroad Company, at Pittsburgh, Pa., have been made, and a similar installation at Broad Street Station is planned in the near future.

One of the most important uses for series systems has been found in the U. S. Coast Defense Service, in sending ballistic data, such as range and azimuth of target, or character of projectile, from position-finding stations to the gunners. This is called "fire-control communication," and is installed in the forts of the U. S. Signal Corps. In a paper presented by Col. Samuel Reber on "Electricity in the Signal Corps," will be found a description of the position-finding system and the desired characteristics of a system of communication for sending this data to the guns are stated as follows: "The system that will successfully solve this problem must be simple in construction, mechanically strong so as not to be affected by the blast, as the receivers are placed close to the guns, rapid in operation, and give a character of record that can be read without liability of error." Since that paper was prepared it has been decided that the receivers must be mounted directly on the gun-carriage and can have no shelter other than that afforded by their

own cases. Add to these requirements the facts that the instruments must be cared for by post electricians, and operated by enlisted artillerymen, messages must be visible at night; and the operation must be independent of rain, salt mists, cold, heat, or tropical insects, and it is apparent that no easy problem is presented.

A special type of telautograph has been designed for this service, and has been adopted by the U. S. Signal Corps for fire-control communication.

In this "service telautograph" the pen-lifter controlling the relay is eliminated and the receiver pen-lifters are operated over a third line wire by the transmitter platen switch directly.

Each gun receiver is enclosed in a water-tight brass case, suspended by springs from the gun carriage directly in front of the gunner. The parts are, as far as possible, made "brutally strong," and the construction is as simple as possible.

The desired rapidity of operation is inherent to the telautograph, and accuracy of record is ensured by careful writing and by the use of a "home" receiver, mounted at the transmitter, where the operator can see plainly, which is connected in series with the gun receivers and records the messages as actually sent over the line.

Freezing of ink is prevented by the addition of alcohol; and rain, mists, and insects, as well as the effects of the blast, are shut out by the metal case. A heavy glass window is placed in the case so that messages can be read without opening the case.

A small incandescent lamp inside the case lights automatically when the receiver is writing and may be lighted by pressing a button at other times, thus providing for visibility at night.

On warships there is a somewhat similar service to be rendered and the performance of this should fall to the army type of telautograph.

Commercial service has given opportunity for the installation of a considerable number of private line telautographs in actual use, and at least three of each of the other typical installations are in operation at the present time.

Much of the improvement in details of construction and reliability in operation has resulted from experience gained in

efforts to perfect service of these commercial plants. The experience leading up to the special arm type of telautograph has extended over a period of about five years, and in the present instrument all the requirements, unusually severe as they are, have been successfully fulfilled.

THE VALUE OF THEORY.

That the electron hypothesis is weakening faith in some of our most cherished theories of electrical action cannot be denied; and the time-honored tenets of magnetism are now subject to challenge as a consequence of the researches in non-ferric alloys by Fleming and Hadfield, * * * . In view of this condition, which may be disturbing to the minds of those who do not properly recognize the real function of theory, it is well to remember that established theory should never be held as an article of faith —as is too often done when connected with names of high authority—but considered only as an acceptable generalization on all the facts in existence coming within the range of the theory. To hold any theory as an ultimate explanation of any set of phenomena implies that every fact relating to the phenomena is known—that nature has nothing more to reveal. It is, moreover, a condition of the growth of human knowledge in any department of science, that whereas the advance never ceases in the acquisition of facts, yet the interpretation placed upon series of facts may vary markedly from time to time. The wealth of acquired material does not shrink, but always advances, sometimes rapidly and at other times more slowly. Nevertheless, the theories embracing the facts, and attempting to explain them, often wax and wither in a single decade. It might really be questioned whether in view of the history of mortality in theories it were worth while attempting to find a theory to fit observation, and whether it would not be better to go on accumulating new materials of facts, heedless of their theoretical relations. The value of theory is, however, that it co-ordinates, or at least seeks to co-ordinate, the facts so as to permit of their proper grouping and presentation in natural sequence. Without the aid of theory, knowledge would constantly become more difficult, by accumulation; whereas, with the aid of theory, knowledge may actually grow easier to acquire, from age to age, in spite of the constant accumulation of material.—*Electrical World.*

GERMAN SHIPBUILDING IN 1904.

One of the most important lines of Germany's industrial expansion has been in shipbuilding. Figures transmitted by United States Consul-General Richard Guenther, Frankfort, Germany, show that in 1904 the German shipyards turned out 278 steamships of 210,999 gross registered tons and 256 sailing vessels of 49,712 gross registered tons. At the beginning of 1905 they had under construction 152 steam vessels of 285,539 gross tons, of which 9 were men-of-war of a total of 69,640 tons. The production for 1904 includes 22 steamers and some sailing vessels, of about 20,000 tons in all, built for foreign account.

REINFORCED CONCRETE RAILWAY TIES.

An interesting use of cement is a method of manufacturing railroad ties recently introduced on the Elgin, Joliet & Eastern Railway. These ties are manufactured under a design originated by R. B. Campbell, general manager of the company, Joliet, Ill.

The tie is 8 feet 6 inches long and 6x7 inches in section, with beveled edges, except under the rails, where it widens to 10 inches for a distance of 8½ inches on either side of the center of the rail. The corners of this widened portion are also beveled to meet the body of the tie. Reinforcement is furnished by two-inch wrought-iron pipe, scrap boiler tubes being utilized for the purpose. Two-seven-foot lengths of these tubes are used for each tie, placed side by side. The tubes are surrounded, sides and ends, by a single thickness of poultry netting. On the center line of the tie below each rail, and parallel thereto, is a 6x8 inch plate of heavy wire netting inserted through specially-punched openings in the pipes. The rail is held to the tie by beveled clip washers and a single U-bolt placed obliquely to the longitudinal center line. A metal plate is imbedded in the tie under the rail.

Very satisfactory tests were made with a number of these ties on a testing machine, and 140 were placed in use, which have been in service from nine to thirteen months. Of these ties nineteen failed in service, but investigation showed that the defects were caused through imperfect mixture, there having been considerable loam mixed with the sand in making the concrete. The results, however, were regarded as sufficiently satisfactory to warrant the manufacture of 1000 more of the ties, which are to be placed in the track of the Chicago, Lake Shore & Eastern Railroad, where the traffic is very heavy. Mr. Campbell states that the ties can be manufactured and sold at a cost of $1.50 to $1.75 each.—*Iron Age.*

SMOKE-PREVENTING DEVICE.

A new smoke-preventing device for boiler furnaces has been invented by Mr. J. S. Pearson, of Glasgow. The system consists of discharging a combination of steam, air and producer gas into the furnace. The three elements are combined and discharged through nozzles fitted to short pipe connections. The resulting chemical action releases the hydrogen in the steam, and combines the oxygen with the carbon in the fuel. The decomposition of the supplied gases is thus completed, and, by combining with the fuel gases and the resulting new gases thus produced, creates great heating power, emitting heavy smoke. The latter, however, decreases in volume toward the tubes, in which there are only flames, and is completely consumed before it reaches the chimney. The steam pressure does not vary with the stoking or cleaning of the furnace, and no ashes or clinkers are formed. The system can be applied to any type of boiler.—*Scientific American.*

ELECTRICAL SECTION.

(Stated Meeting, held Thursday, March 30, 1905.)

The Alternating Current Generator.

BY DAVID B. RUSHMORE.

[This article is substantially a historical sketch of the origin, development and present status of this important class of electric generators.—THE EDITOR.]

The dynamo dates from the discovery by Faraday, in 1831, of the law of electro magnetic induction. The previous discoveries of Oersted, in 1820, regarding the relative positions of a permanent magnet and an electric current, and of Arago and Sturgeon of the possibility of making magnets from pieces of soft iron by passing an electric current around them, led Faraday, in an unparalleled series of experiments, to discover that important law, and on September 4th, of that year, was first coined the expression "lines of force."

Faraday's disc generator, constructed in 1831, was an experimental unipolar and is of interest as being the first dynamo electric machine. The early development of the dynamo consisted of many modifications of magneto generators, and it was about 1856 that the first commercial use was made of such apparatus, when the embryo of our present arc lamp was supplied by current from a machine built by the Campagnie de l'Alliance, which had been developed by VanMalderen and Nollet. This installation was in the lighthouse. Until 1876 there was a large amount of work done in the development of dynamo machines, most of which were, however, for the generation of direct current and concerned with the work in which are associated the familiar names of Siemens, Wheatstone, Pacinotti, Wilde, Gramme, Lontin, de Meritens, Brush, Weston, Edison, Hefner-Altenech, Ganz and Schuckert.

What might justly be called the first practical alternators were those built by Gramme, between 1876 and 1880. These are

internal revolving field generators with direct-connected exciters, and were demanded by the desire to have both carbons of the Jablochkoff candles burn evenly, which could not be done with the direct current machines then in use. The armature winding is stationary and external, but is the same as the previously well-known Gramme ring construction. The armature is wound with four separate phases and the earlier machines have eight poles on the field and eight sections on the armature. The corresponding coils in the different sections were connected in parallel or series, as was desirable. It was with these machines that the term "exciter" was first used. The special interest of these machines to-day is the fact that they were of the internal revolving field type with a polyphase armature winding and having direct connected exciters.

Following the Gramme machines we have a development of alternators by de Meritens, Hefner-Alteneck, Ganz, Schuckert, Zipernowski & Deri, and, in more recent years, such machines as designed by Kapp, Mordey and Ferrenti.

The first machine used to any extent in this country was developed about 1886-7. It consisted of a stationary external field with inwardly projecting pole pieces, the cast-iron pole pieces and yoke being cast together. The pole face was beveled slightly at the armature surface, but was not extended beyond the pole core. The internal revolving armature consisted of discs built up directly on the shaft. There were six ventilating holes running lengthwise on the shaft but none at right angles thereto. Wooden pieces were secured to the ends over which the flat pancake coils were wound, the ends being bent back at right angles from the cylindrical surface. Wooden pieces were also placed in the center of the flat pancake coils, and later the same were placed between the adjacent coils. The core was covered with insulating material on which these wooden strips were fastened, being held by screws, which passed through the insulation into the iron core. After the coils were wound by hand on the surface of these machines, another covering of insulation was placed around the armature, which was held in place by bands of piano wire, and on the ends by end bells. These machines possessed excellent regulating qualities, good wave form, and good ability to radiate heat. They were, however, very easily injured, and the entire winding

could be stripped from the armature by a piece of metal falling thereon or by the wear of the bearings, allowing the armature to strike the pole pieces.

These early machines were all for 15,000 or 16,000 alternations and were, of course, single phase. The pulsating armature reaction from these alternators caused the pole pieces to heat, and the first change was to cast laminated poles into the field yoke. The next change was to make a toothed armature with one tooth per pole and one armature coil per tooth. These armature coils were machine wound and were insulated separately from the core. They were drawn beneath the projecting top of the teeth and were held in place by a wooden wedge driven between the adjacent coils. Brass shields fitted over the projecting ends of these coils, completly protecting them from the possibility of external injury. These iron-clad armatures were a great improvement mechanically, and it was possible to subject them to very rough handling without injury. The concentrated winding gave poor regulation, a bad wave form and poorer heating qualities than the smooth core type. The considerable pulsation of magnetic reluctance caused heating. The quickness and ease of repair, however, made these machines a decided improvement over the old ones.

There were a considerable number of modifications of both the smooth core and toothed machine with regard to compounding. In some cases an auxiliary winding was placed on the armature and the current therefrom taken through a two-part commutator to either the main or auxiliary field. In other cases, the main current passed through a series transformer, either consisting of the arms of the machine itself or a separate transformer external to the armature. From the toothed form, a polyphase machine was developed known as the Plus 2 type, in which the revolving armature had two teeth more than were poles on the field. Taps led into the armature at points 90° apart and gave the desired quarter-phase relation of the current. The next step was to distribute the winding in many small slots, as is now done. This allowed the use of machine-wound coils, which were easily placed on the armature, and were held in place by wedges passing over the slot. With this winding, better regulation and better wave form were obtained, as well as improved ventilating qualities. The sup-

porting arms of these armatures were used for series transformers and by means of a two-part commutator, the machines were compounded. Radial ventilating ducts were also introduced, and about this time the use of oil rings instead of the oil drip became general. The revolving armature with a distributed winding was built in many sizes and with a considerable variation of mechanical construction.

The demand for higher voltages led to the practice of building the armature external to the field and revolving the field. This allowed the armature circuit to remain unbroken, the only sliding contacts being those for the low voltage field excitation with carbon brushes on cast-iron rings. It also allowed the armatures to be wound directly for voltages as high as 13,200. The field coil is made of copper strip wound on edge, making a large saving in the amount of material necessary for this part, and so making the field coil practically indestructable by heat. Simultaneously with these improvements, a great change has taken place in the insulation used for armatures and the use of oil in some form having become the best practice.

NIAGARA FALLS GENERATORS.

The recent development of alternator design is well shown in the different types of machines which have been furnished the various power stations at Niagara Falls. These machines have been so frequently described that only the points of particular interest will be touched upon.

The original design consisted of the umbrella type external revolving field supported from the top of the shaft. This gave the advantages of combining the fly-wheel with the revolving field and with having the centrifugal force of the poles in opposite direction to the magnetic pull. It also relieved the bolts holding the poles of any strains due to centrifugal force. The revolving field ring was forged from an ingot of compressed nickel steel without a weld, and the poles were solid steel castings held to the rim by bolts. The field coils were held in place by the projecting tips of the pole. A rectangular wire was used in the field coil, which was wound up in solid form and was not ventilated. The collector was placed on the upper end of the shaft and a bridge structure ran over the machine in

order to give access to the collector and bearings. The armature slots were nearly enclosed with two conductors per slot and insulated with material, which was largely mica. The bolts clamping the armature iron passed through the laminations which were ventilated with six one-inch ducts. The ends of the armature winding were left unsupported. On these machines thrust bearings were used as the direction of the pressure on the vertical shaft varied with the load.

The second lot of machines were made by the same manufacturers as the first, but a number of changes were introduced which experience had shown to be desirable. The nuts on the field ring were sunk into the metal. The field coil was very much changed, being wound with a number of layers of copper strip wound on edge, and the whole being well ventilated with ducts through the winding and holes cored into the bobbin. The field coil insulation was largely mica and shellac. In the armature twelve half-inch ventilating spaces were used instead of six one-inch, as in the first machine. The bolts clamping the iron did not pass through the laminations and much better work was done on the punchings, so that less finishing of the slots by filing was required and in this way the heating considerably reduced. The slots were made more numerous and smaller, so that there was but one conductor per slot and the armature winding was reduced 15 per cent. With this reduction came also a reduction in length of air gap from one inch to three-quarters of an inch. Like the first machine, the second had also very bad regulation, which was at that time considered advisable as giving the small cross currents and also as placing an automatic limit to the current output of the machine. The ventilation of the first machine had not taken place as expected and drag hoods were placed on the revolving part of the second machine. The armature was also cooled by means of circulating water in heavy copper tanks placed back of the laminations.

The third machines were built by a different manufacturer, and were considerably changed in design. The purchasing company, however, demanded that in general appearance and arrangement that they conform to the previous types. The collector rings were placed below the armature and the bridge over the machine was omitted. The regulation was made very much better than in the old machines. The armature coils were ma-

chine wound and consisted of rectangular cable placed in open slots with two coils per slot. The poles, instead of being solid, were laminated and the load losses thus materially reduced. The method of ventilating was also entirely changed, so that the air was drawn into the center of the machine from below and forced out at holes in the upper part of the revolving ring.

The fourth type of Niagara machine was made by the same manufacturer as the third but the type of machine was entirely changed. In this generator, the internal revolving field was used and while this choice was due to the development which had taken place in this style of machine it was allowable in particular because of the improvements made in water wheel governors, which necessitated a smaller fly-wheel capacity. Numerous ventilating ducts were placed in the armature. The slots were open and contained two conductors of standard copper cable. The ring of the revolving field is built up of laminated steel sheets and the poles are built up separately of the same material. These are then held in place in the field ring by dove-tails and keys. The armature coils are supported on the ends outside of the laminated iron to prevent any binding effects due to short circuits or heavy currents. In other respects, the generators are all standard revolving field type of construction.

The fifth Niagara machines are double the output of the previous ones, or 7,500 K.W. each. The mechanical structure of the armature frame differs somewhat from the previous machine, but in general the variation is simply one of size. In this machine the solid bar is used for the conductor in the bottom of the slot and a stranded cable, which is passed through the vacuum japan treatment, for the conductor at the surface.

In this country modern types of alternators are divided into two distinct classes, the inductor type and the revolving field type. The revolving armature with external field is still used to some extent. Descriptions will be given of the inductor type alternator as developed and manufactured by the Stanley Elec. Mfg. Co., and of revolving field generators made by the same concern, illustrating the engine type and coupled or water-wheel type. Also, a brief description of modern forms of turbo-alternators.

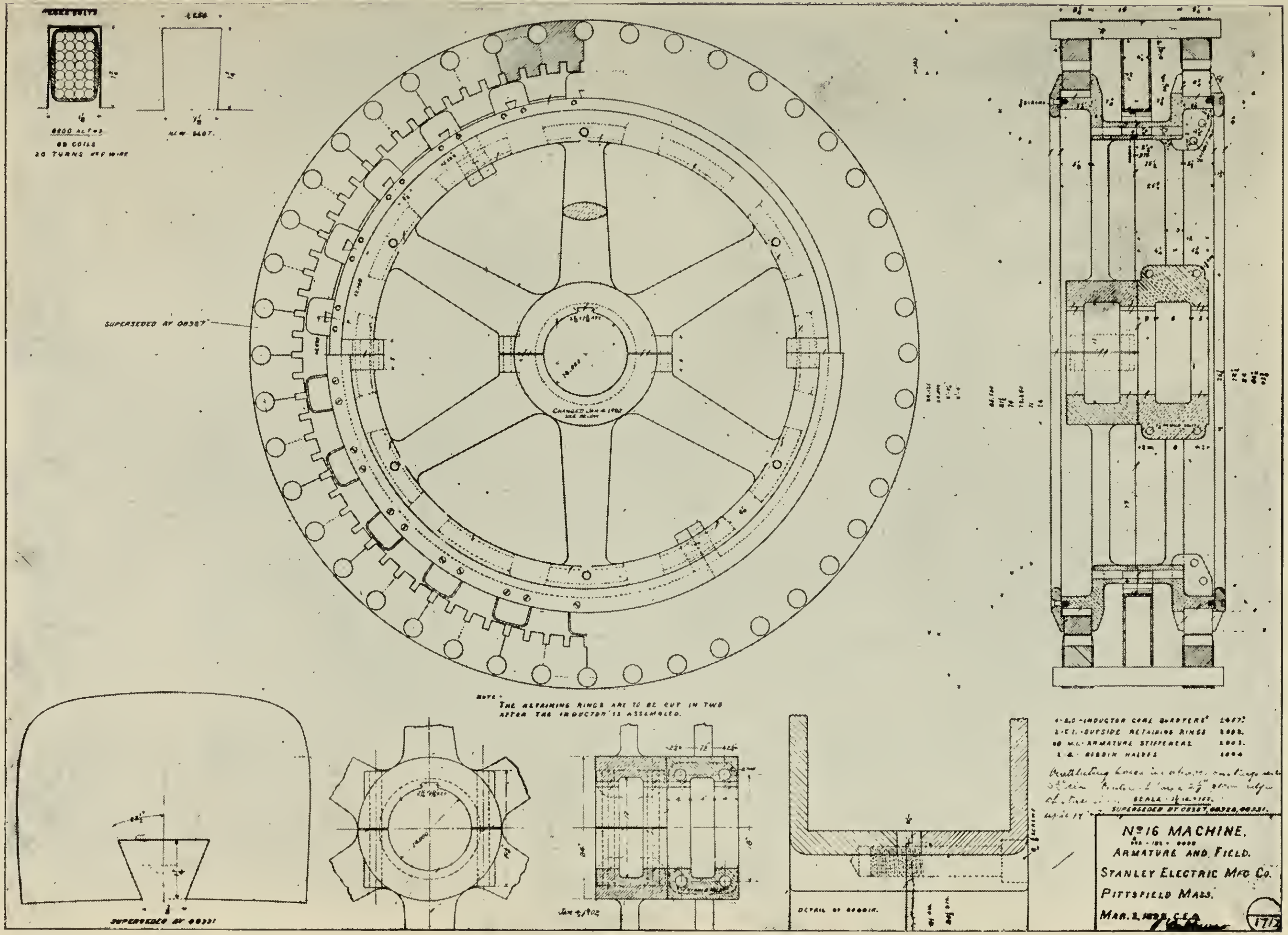


Fig. 1. S. K. C. inductor alternator, engine type, 300 KW.—182 R. P. M. 8000 alts. Winding on armature not shown. Details of slot, field bobbin, inductor punching, and hub.

INDUCTOR ALTERNATOR.

The inductor alternator was developed in this country about twelve years ago, and was at that time decidedly superior to any other machine on the market. The mechanical construction is clearly illustrated in Figs. 1, 2, 3 and 4. These machines are made either engine type, coupled or belted, depending upon

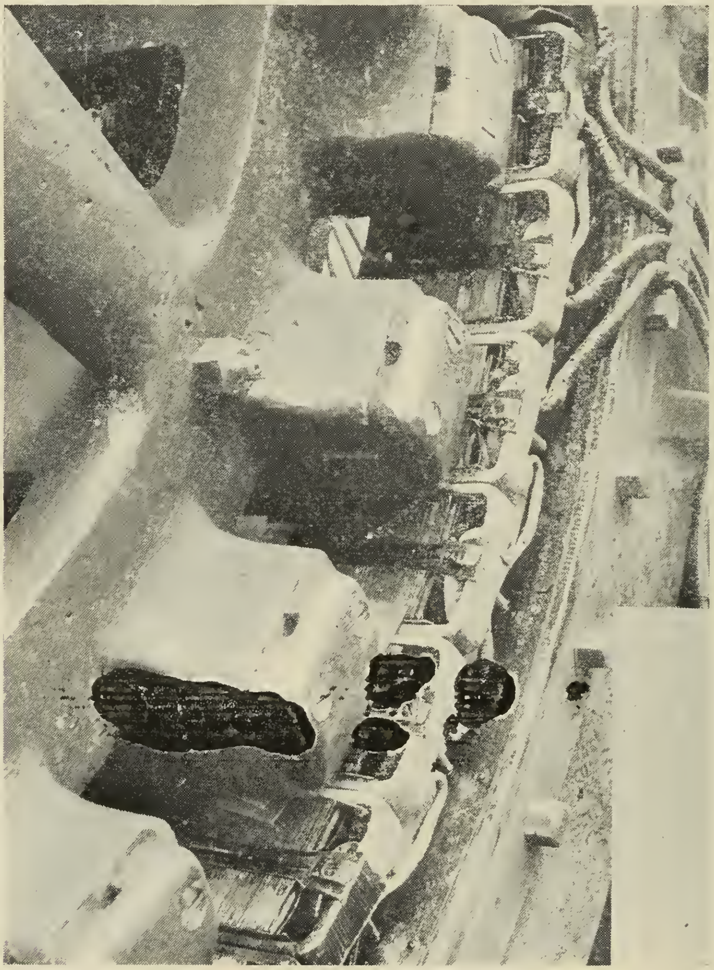


Fig. 2. No. 16 machine, 843. Coil clamps and connections.

the conditions. A considerable variation in mechanical construction exists in each type. The armature frame may either be made of cast-steel shell or tie-bar construction, depending upon the size of the machine and the output per pole. Where kilowatts per pole exceed a certain figure, a limited peripheral velocity may necessitate the use of a cast-steel shell. In the standard tie bar construction, the external stationary armature

is supported by four cast-iron rings which are parted in either an horizontal or vertical plane. The armature laminations are held between the bars on outside rings and are supported on tie bars which connect the cast-iron rings as shown, while supporting the active iron, and, also, act as part of the magnetic circuit of the armature, although the magnetism of these bars undergoes no variation. Half of the bars butt against the outside rings, as shown. Between the two metal rings is a pipe

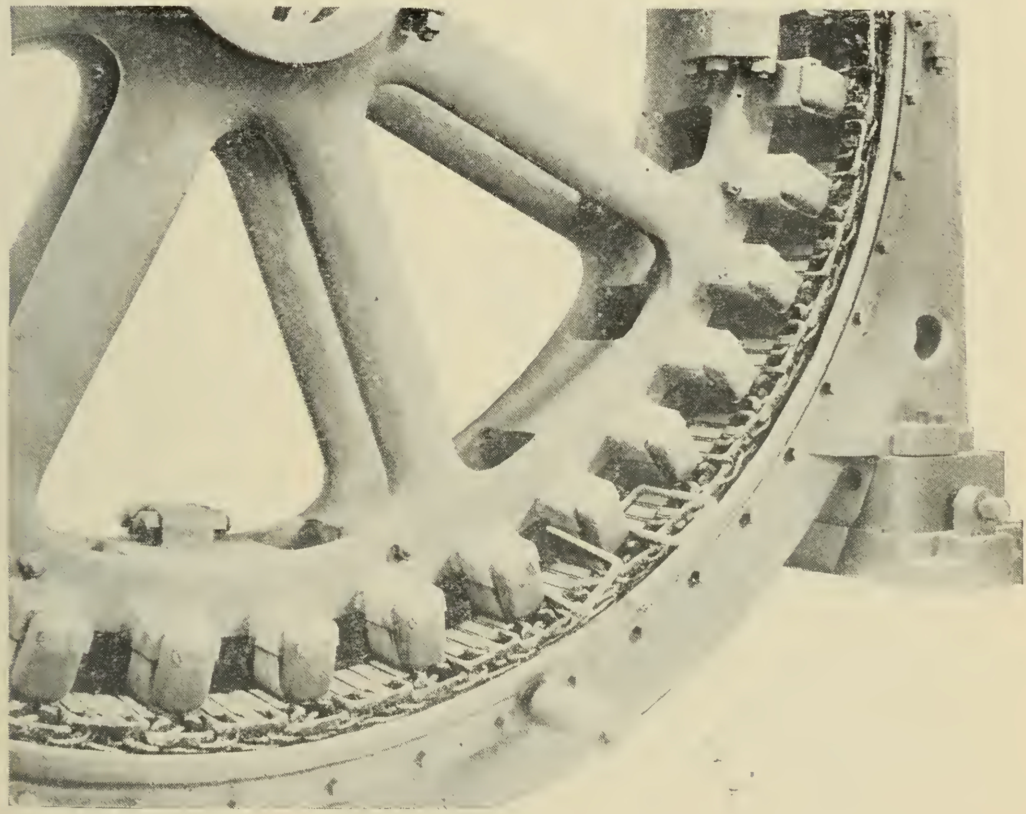


Fig. 3. S. K. C. inductor alternator showing method of removing armature coil.

washer which fixes the distance between these rings. The outside rings in some cases have the shields to protect the armature coils cast in one piece with the ring. In other cases the shields are separate and are fastened by screws. It is seen that the space between the two center rings is but partially occupied by the magnet bars and that a large amount of space, affording easy egress for the air circulated by the revolving inductor is offered, thus giving excellent opportunities for ventilation of field coils and inner ends of the armature winding. The laminated iron in these machines consists of the best obtain-

able quality of sheet steel, made according to rigid specifications, which is afterwards punched out at the shop and thoroughly annealed and japanned by special processes, the development of which is the result of many years of experience. On the ends of each section of laminated iron are sheets of much heavier rolled plate, called stiffeners. These keep the laminated sheets in shape and prevent their spreading apart.

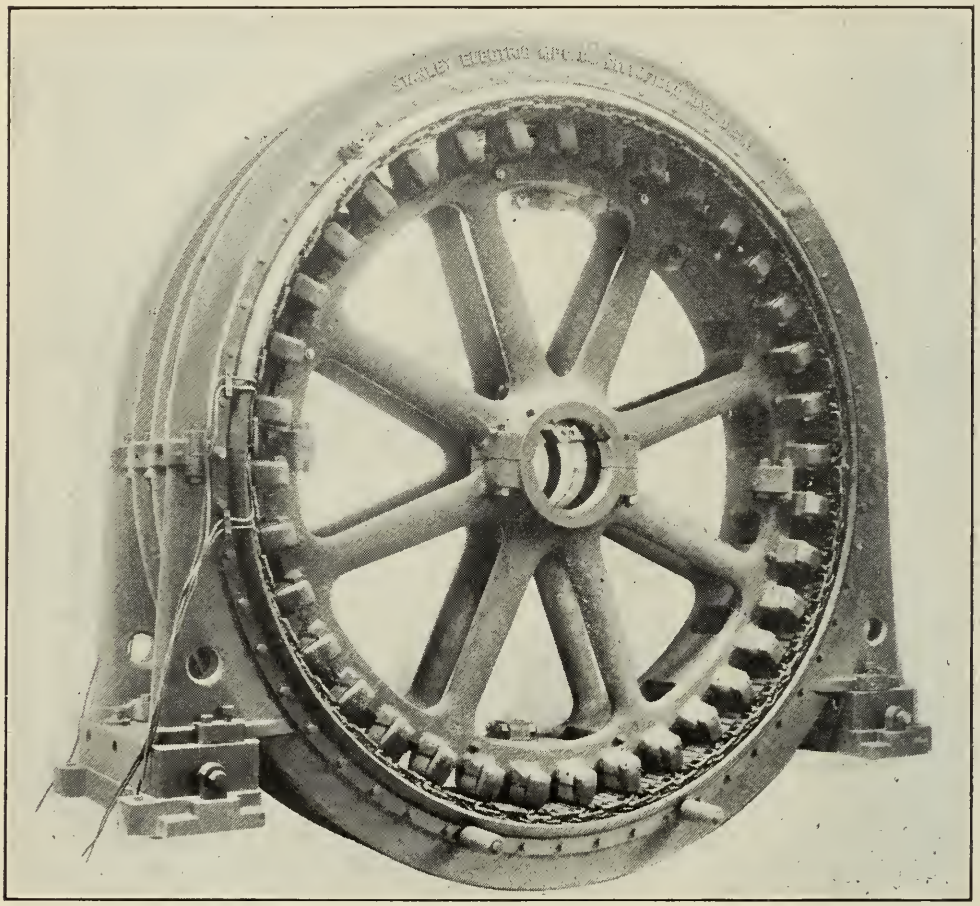


Fig. 4. S. K. C. Indicator Alternator Complete.

The inductor alternator has but a single field coil and this is supported on the inside of the armature structure and does not revolve. The coil consists in the larger machines of a flat copper strip wound inside a brass bobbin, the sections of winding being separated from each other by a wide ventilating duct passing radially through the center of the coil. The strips are insulated from each other by means of oil cloth and the whole winding is insulated from the bobbin by means of specially pre-

pared insulating material. The winding of the field coil is thus seen to be well protected from any possible mechanical injury and to be exposed to excellent ventilation on the sides of the coil and also through the center by a current of air set up by the skeleton revolving mass known as the inductor. The armature winding is placed in slots in the laminated iron and is held by either clamps on the ends of the coil, as in some of the old machines, or by wooden wedges across the top of the slot in the latest types. The armature winding is in almost all cases what is known as the concentrated winding. This gives a firm coil with very short ends, needing no support on the ends of

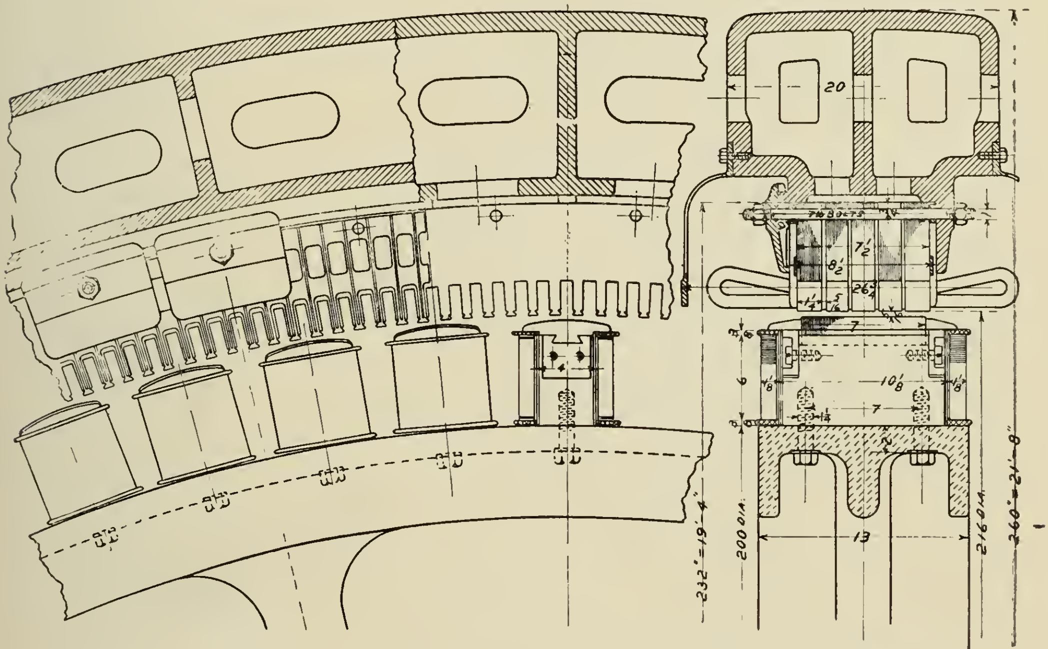


Fig. 5. A typical modern revolving field alternator.

the coils to prevent a bending effect from short circuits. In the larger machines, the armature coils can be removed without disturbing the machine in any way. It is usual to wind the armature with two coils per slot, although certain cases arise in which the one coil per slot arrangement is necessary. The entire armature winding is accessible for inspection when the machine is not in operation and in a way not possible with any other type of machine. The armature winding consists of either wire, strip or stranded cable wound on suitable forms and properly insulated. Where stranded copper cable is used and in all other cases where it is advisable, the winding is given

a vacuum compound treatment which completely fills the interstices of the coil with an insulating japan. This is then pressed into shape and baked so that a uniform solid structure results which cannot be injured by vibration, and which is practically indestructible under such conditions of operation as should exist. These machines may be wound for one, two or three phases, and in the latter case the winding may be for either a star or delta connection. In the insulation of the armature coils, the best and most recent type of oil cloth insulation is used, no micanite being permitted in any part of the coil. Such oil insulation if not subjected to too great a temperature remains for years in practically the same condition as when first placed on the coils. The revolving part, known as the inductor, consists of a skeleton steel casting on which are

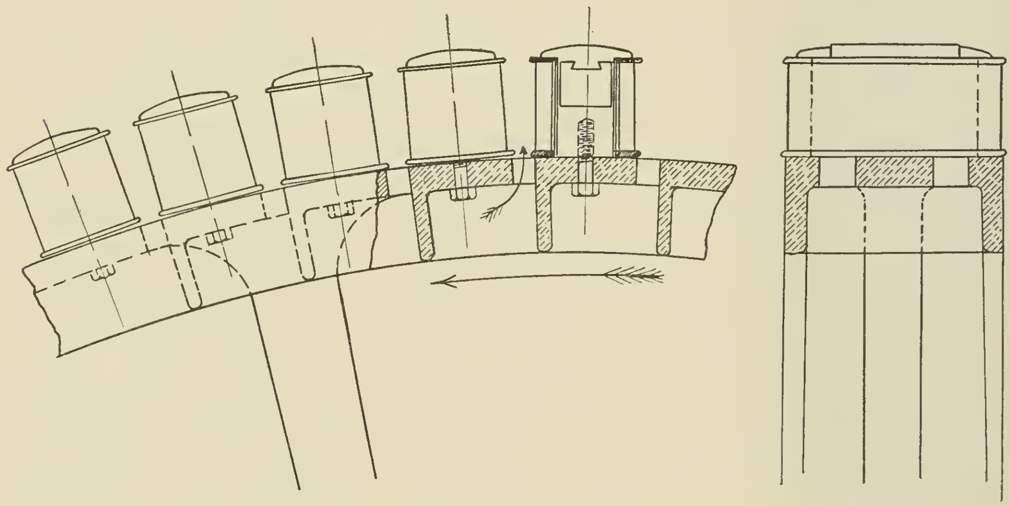


Fig. 6. Improved method for ventilating revolving field alternator.

mounted pole and projections of laminated steel. The external magnetic part of this structure is mounted upon arms and held in the usual manner, and the castings are sub-divided in a variety of ways as best suited to the particular machine as regards the convenience of handling. The central part of the revolving casting is cored out at intervals around the circumference giving one-third of the space in ventilating holes and about two-thirds of solid metal, which arrangement affords the best possible ventilation for the field coil, allowing a blast of air to be thrown against the three sides and forced through the center ventilating space. The rims on which are mounted the pole laminations are cut away between the polar projections in

the later machines. This style of construction, known as the skeleton inductor, allows the armature coils to be easily removed from the larger machines, affords the best possible ventilation and considerably improves the electrical characteristics of the machine with regard to exciting power and regulation, the actual leakage in this type of machine being reduced to approximately 5 per cent. The pole is so formed as to give a magnetic field varying as a sine function of the angle from the center of the pole, which, with the concentrated winding, gives a sine wave of E.M.F. This is an important feature of the inductor alternator and is very difficult to obtain in the revolving field types except with distributed windings. The peculiar electrical operation of this machine is that the flux through the armature pulsates through the armature coils and swings through a certain angle with respect to the armature iron. This allows the use of high densities in the laminated iron without causing heating of the same.

The regulation of the inductor alternator can, of course, be made anything desirable, and, in comparing this type of machine with that of the revolving field alternator, any slight difference in weights may not necessarily mean a similar difference in cost.

In comparison with revolving field machines, the inductor alternator possessing the same efficiency will have a higher armature copper loss and a lower iron and field copper loss. This accounts for high efficiencies at light loads and the fact that the iron in the inductor alternator armature heats but little prevents local rise of temperature in the armature coils.

The characteristic points of this type of machine are as follows: No revolving wire; no sliding contacts; a single field coil; the field coil entirely protected from mechanical injury; the possibility, in larger sizes, of removing the armature coil without disturbing the machine; the small exciting power necessary; the sine wave of E.M.F. with concentrated winding; the proportionately short length of idle conductor in the armature; the unequaled ventilation of armature winding; the absence of any necessity for supporting the armature coils at the end, and, in general, the machine demanding the minimum of care and attention.

REVOLVING FIELD ALTERNATORS.

A typical modern revolving field alternator is shown in Fig. 5. The active material of the external stationary armature is supported by a cast-iron box frame. Armature frames are made in a large variety of styles and sections abroad, but in this country the section shown may be taken as standard. The frame may be divided either horizontally or vertically, and in some of the larger machines is divided into a greater number of parts to facilitate shipment and erection. The box form used gives the best utilization of the material and affords an easy means for ventilating the armature laminations.

These laminations are held by dovetails cut into ribs cast on the armature frame, which ribs run parallel with the shaft of the

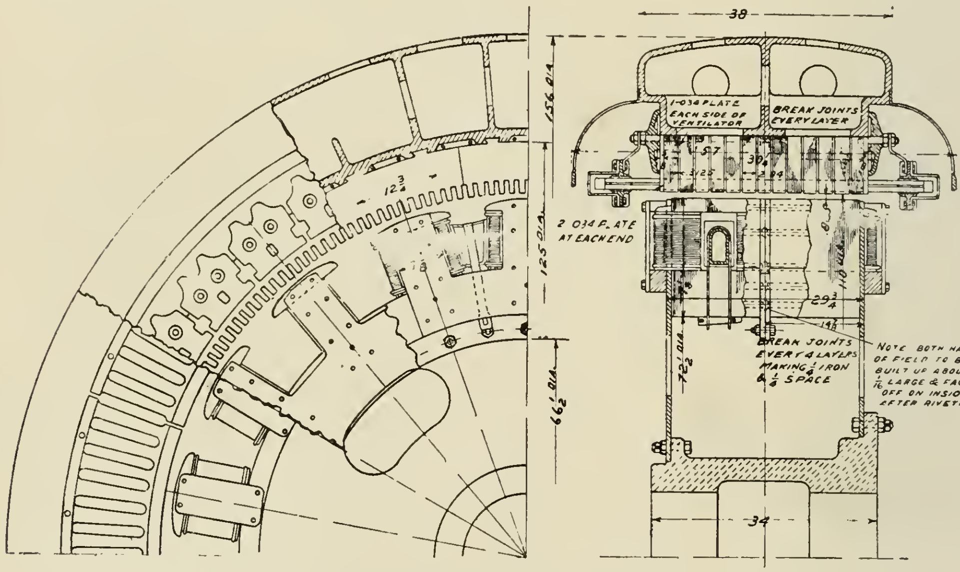


Fig. 7. 5000 K.W. water-wheel type revolving field alternator.

machine. There are also numerous methods for supporting the laminations but this method of dovetail suspension is the most substantial and best. The laminations are divided lengthwise of the machine by many ventilating ducts which allow the free passage of air from the revolving field and are held together by retainers at each end, clamped by bolts passing entirely back of the laminations. This laminated iron is punched, annealed and japanned in the same way as previously described, and its proper manufacture is one requiring great knowledge and skill to obtain the best results.

The armature coils are machine-wound and are completely

insulated before being placed in the open slots. The use of open slots is of great advantage in machines wound for high voltages, as it allows the complete insulation of the coil before it is placed on the machine, and with the oil cloth insulation used where the oil is brushed on each wrapping of cloth and separately baked, the insulation of the entire coil consists of a large number of coatings of an oil film, each complete in itself.

Stationary armatures allow the electrical circuit to be unbroken, which is of great advantage in high voltage machines.

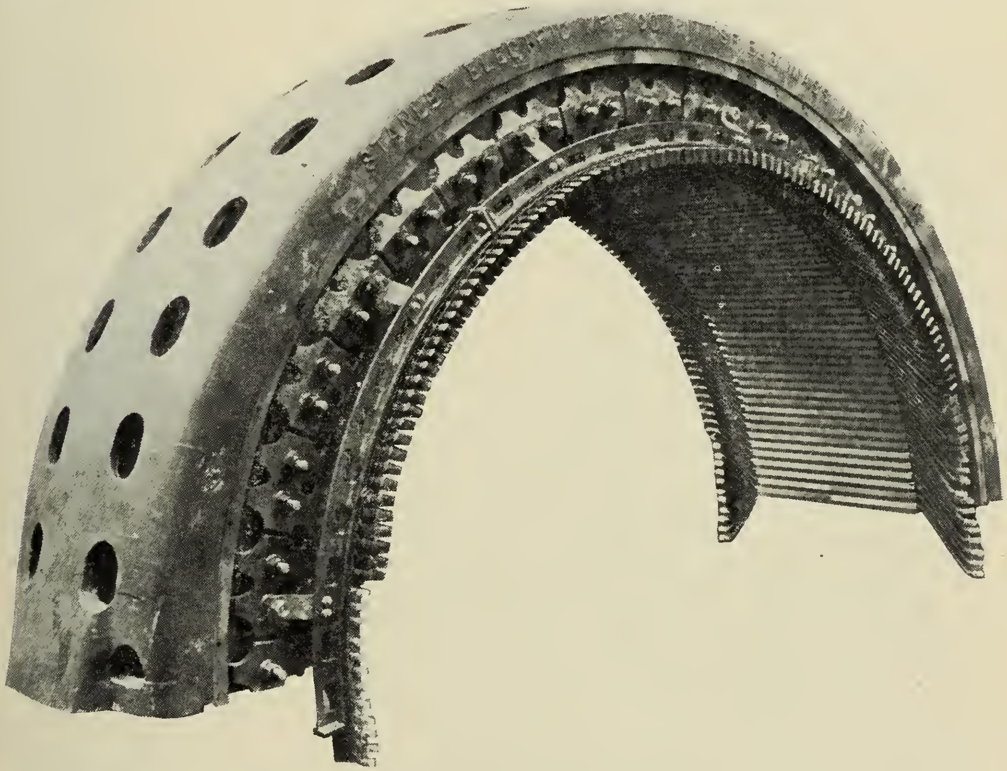


Fig. 8. Upper half of armature frame without end shields, showing method of supporting end connections.

Most revolving field alternators have a distributed winding giving two or more slots per phase and by proper beveling of the pole a sine wave of E.M.F. is obtained. The greater the sub-division of the winding, the better the wave form, and the better the opportunities for dissipation of heat.

The proportionally large amount of space occupied by insulation in high voltage machines limits the possibilities of winding distribution from both mechanical and commercial considerations. Open slots allow the coils to be machine wound and be subjected to vacuum compound treatment and completely in-

sulated before being placed in the machine. With cable conductors this is almost a necessity in order to obtain firm coils and to properly insulate the strands.

High voltage machines necessitate good insulation between the conductors in a coil, as well as between the conductors and iron, a matter not always sufficiently emphasized. By completely insulating the coil before placing it in the slot, this may be accomplished, and in high voltage machines, especially those used as synchronous motors, it is a very important factor.

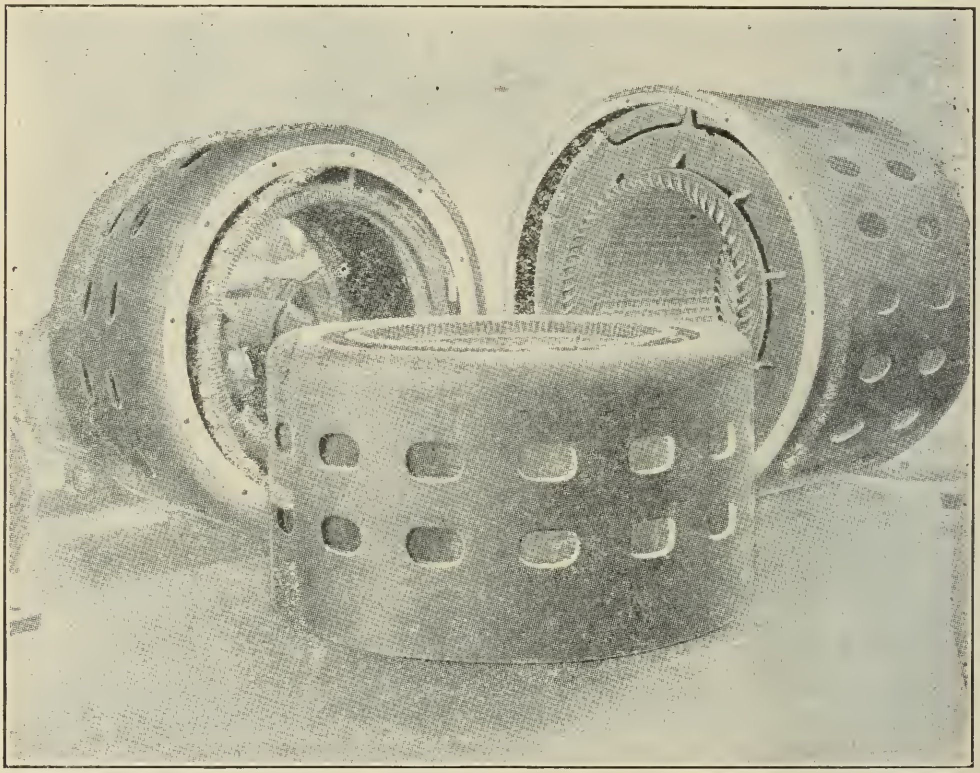


Fig. 10. Stationary armatures for turbine-generators.

Open slots in general necessitate laminated pole pieces, which are, however, of advantage both from a standpoint of symmetrical construction and in preventing an increase of iron loss under load, even though there may be no Focault losses in a solid pole piece on open circuit. Laminated poles allow a quicker response in voltage to any change of excitation.

Poles are fastened to revolving field rings in a large variety of ways. Where the poles are separate from the ring, they are usually held by bolts which enter keys running lengthwise

through the laminated poles in machines of comparatively low peripheral speed, and where the speed is high the laminated pole is dove-tailed and keyed into the ring.

The development of the revolving field alternator brought with it the edge wound copper strip field coils, one of the great advantages of this type of machine, and the manufacture of which illustrates a high development of machine-shop practice.

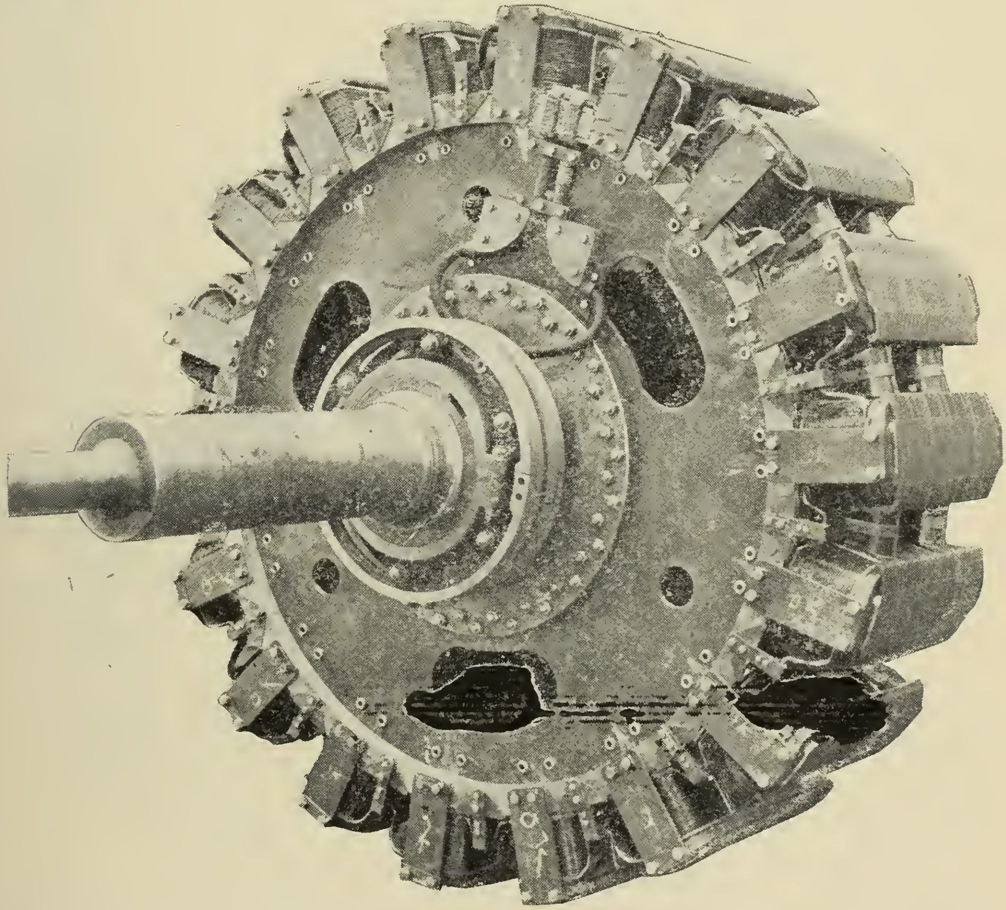


Fig. 9. Revolving field showing details of mechanical construction, illustrating careful consideration of stresses due to centrifugal force.

This strip-wound field coil is of excellent mechanical structure, which cannot get out of shape and which is in very little danger of injury from over-heating, the external surface of the coil being entirely exposed to the air, it being impossible for any local rise of temperature to take place.

The proximity of the field coil to the armature surface acts as a damping device and is in most cases sufficient preventive against hunting troubles.

Solid field rings are in this country universally made of steel and made cast in one piece with the arms and hub, or the latter may be made of cast-iron bolted to the field ring.

The ventilation of the revolving field alternator is somewhat inferior to that of the inductor, and to overcome this a number of methods of construction are used. One of these consists in casting holes in the field ring between the poles and by suitable end rings and cross-webs which act as fans. Fig. 6.

Engine-driven revolving field alternators of large output,

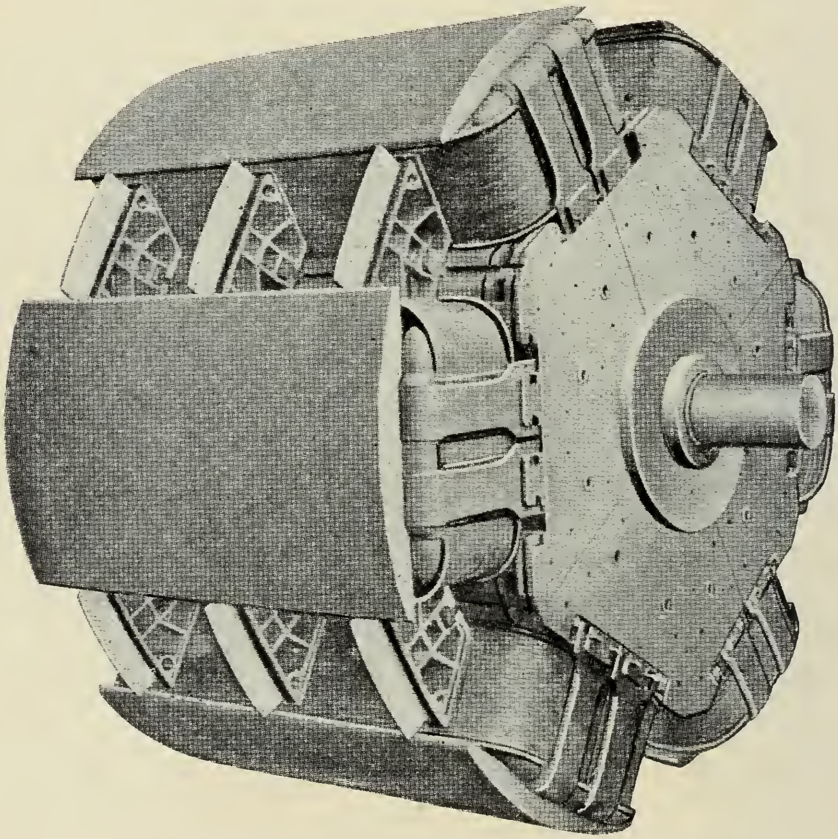


Fig. 11. Revolving field for a 5000 KW. alternating current turbine generator.

especially for the higher frequencies, are often of such dimensions that the revolving field and fly-wheel can very suitably be combined. In such cases the fly-wheel is usually built up of steel plates.

WATER WHEEL GENERATORS.

The use of heads ranging from 1,500 to 2,300 ft., and the demand for units of large output, in many cases 5,000 K.W.,

has led to the development of a water-wheel type of generator, machines and the standard revolving field generators is princi-Such generators must be built to stand an increase of speed of

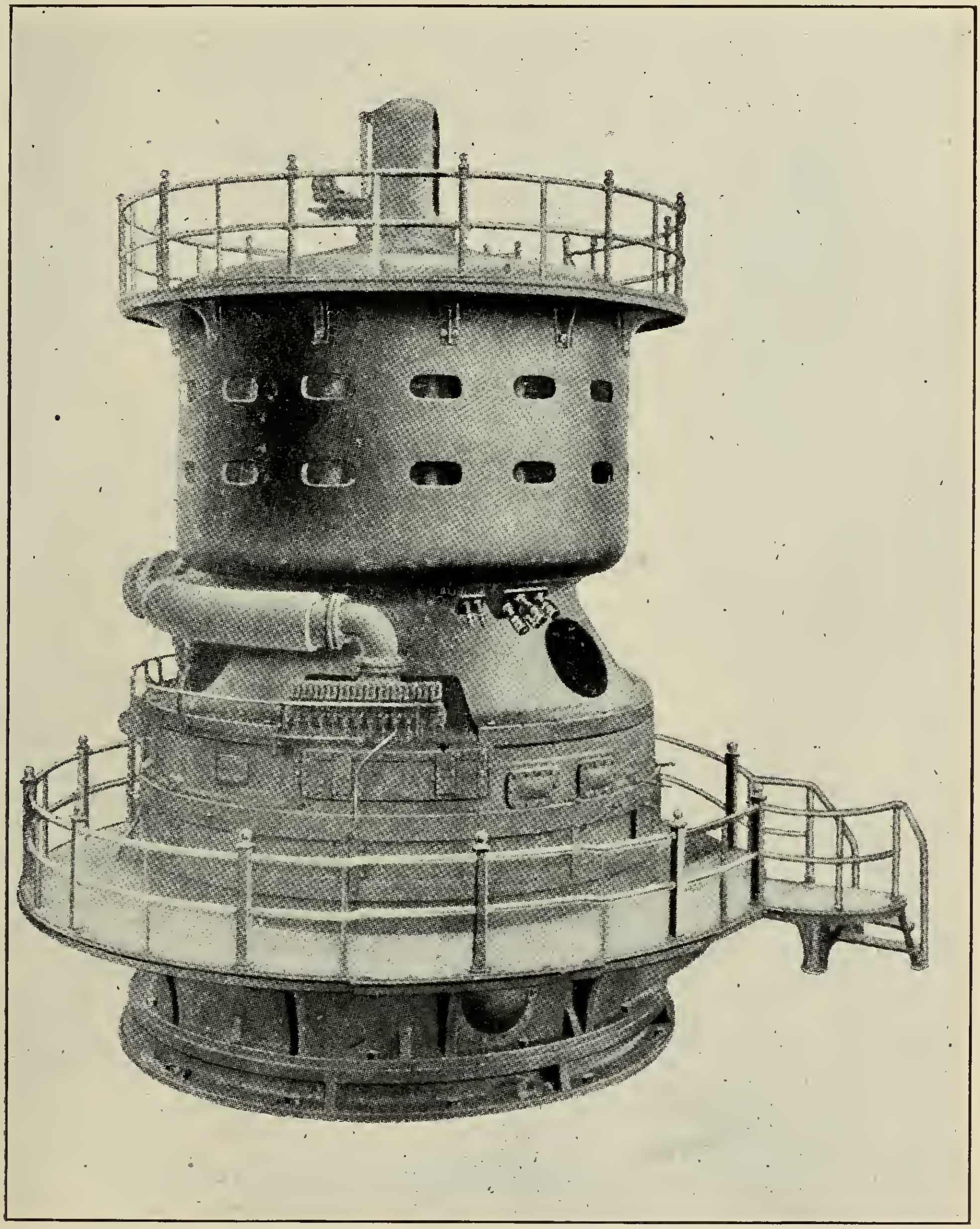


Fig. 12. 5000 KW. Curtis steam turbine direct connected to 5000 KW. three-phase alternating current generator.

something less than 100 per cent., and for this reason the mechanical design takes precedence over the electrical.

The difficulty of hauling these machines for distances up to forty miles to inaccessible power house locations and over bad

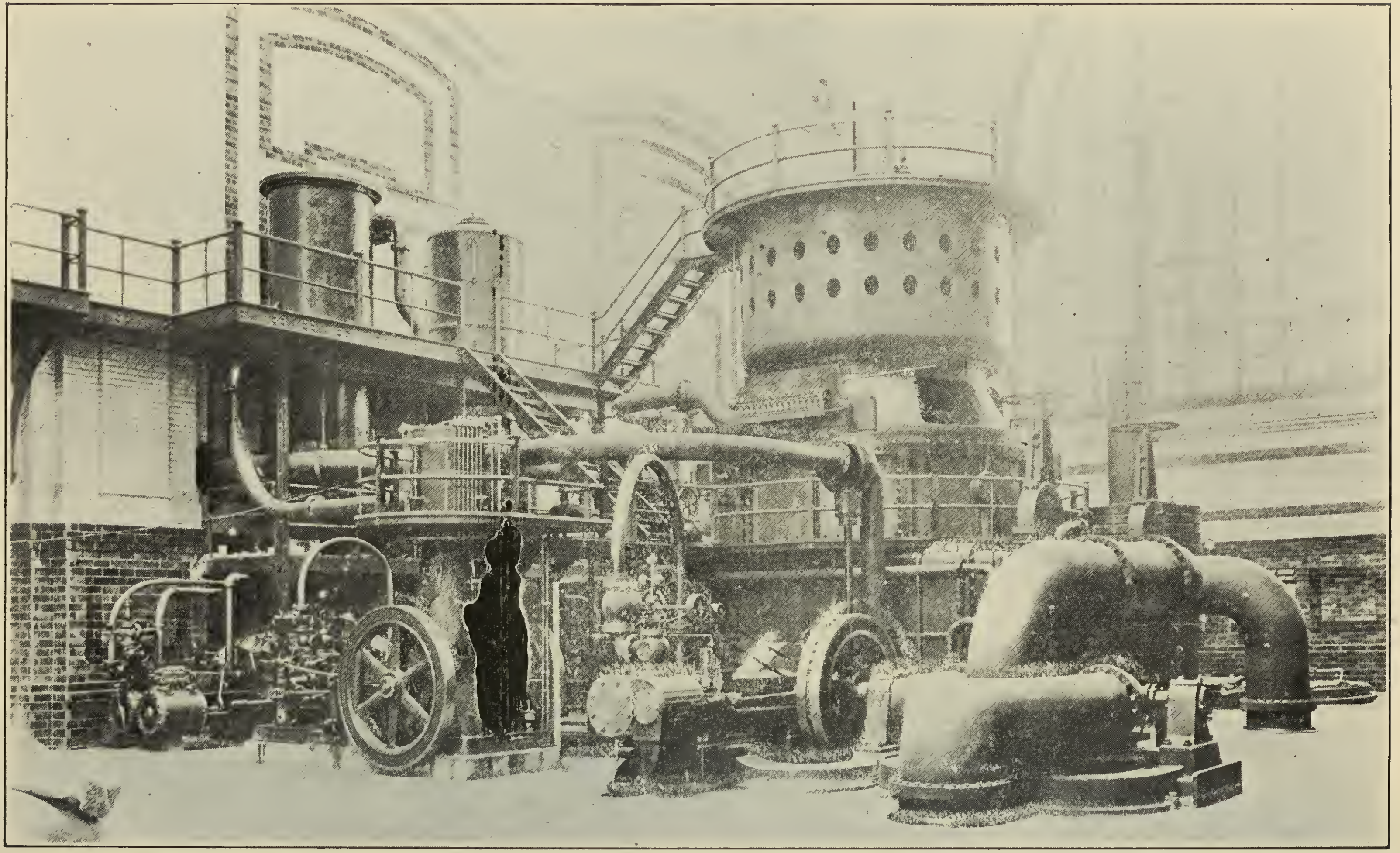


Fig. 13. 5000 K.W. Curtis turbine set with auxiliaries.

roads often influences the mechanical design. An illustration of a machine designed for such conditions is shown in Figs. Nos. 7, 8, 9. This machine was built by the Stanley Electric Mfg. Co. for the California Gas and Electric Corporation, and is a 5,000 K.W. three-phase revolving field generator, running at 400 revolutions and giving 2,400 volts, which voltage is raised by transformers to 60,000.

The stationary armature is a more or less standard construction, except that the weight is reduced to a minimum and the details of every part are most carefully designed in order to make the structure as light as is consistent with necessary strength. The revolving field is of novel construction. The ring and poles are built up of laminated steel sheets, each punching covering two poles and the section between them. In one punching the pole part on one end extends to the air gap; on the other to the bottom of the pole tip. These punchings, $\frac{1}{8}''$ thick, are built up in pairs. In this way the resultant structure gives a solid pole while the space between the poles consists of alternate spaces of $\frac{1}{4}''$ air gap and the same amount of laminated iron. The field coils are cemented into one solid structure and each individual coil, as well as every separate part of the revolving field, is carefully weighed and balanced. The revolving field ring, built up of laminations, is mounted on the hub by steel end plates, as shown, and is divided into two parts to facilitate transportation by the insertion of two plates in the center, which are similar to the end plates, except for the connection to the hub. After the field coils are placed on the pole, the tips, which are inserted between the alternate laminations, are then put in place and bolts running lengthwise through these tips and the alternate projecting pole pieces, passing also through retainers over the ends of the field coils and holding same in place.

TURBO-ALTERNATORS.

In turbo-alternators, the considerations of the mechanical design are of first importance, and the difference between these machines and the standard revolving field generators is principally one of comparative output and speed, and of methods and devices for supporting the structure under the necessarily great mechanical strains.

Laminated steel is a material of known strength which can be relied upon, and, therefore, is largely used in the construction of the revolving field for turbo alternators. The central ring is built up of these steel sheets and so arranged that the poles are built up and riveted separately, and introduced endwise into the ring structure through proper dovetails and are held firmly in place by keys. The unbalanced component of centrifugal force at right angles to the side of the field coil is taken into consideration by placing proper wedges between adjacent coils. Straps passing over the coil ends securely hold these parts in place. Other types of turbo alternator construction are used, but that shown in Figs. 10, 11, 12, 13, may be taken as representative of the vertical type used in this country in connection with the Curtis turbine.

ALLAYING THE DUST NUISANCE ON HIGHROADS.

For some time past experiments have been carried out in England with several media such as westrumite, and so forth, for overcoming the dust nuisance on the high roads, which is created more especially by automobiles. These materials, however, have proven only partially successful. The results of some later experiments in this direction which have been carried out in Liverpool were recently described by Mr. A. Lyle Rathbone, deputy-chairman of the Liverpool Health Committee in a lecture at Liverpool. The surface of a selected roadway was coated with creosote oil mixed with resin. This mixture gave the cleanest and nicest appearance, while the surface coated with ordinary petroleum was the least lasting. Next in order came mixtures of creosote oil with tallow, and hot creosote oil. Heavy coal tar waste oil lasted rather longer than the creosote oil, and was very much cheaper. Considering the experiments as a whole, the result would seem to point to eventual success with the use of some classes of oil in the place of water on macadam roads.—*Scientific American.*

EFFECT OF HIGH TEMPERATURE ON THE STRENGTH OF STEEL.

Professor Bach has made some experiments to determine the effects of high temperature on the strength of steel, using groups of four bars each. The temperature of the testing of the several groups were: Atmospheric, 390, 570, 750, 930 and 1020 degrees F. On one bar the test at ordinary temperature showed a strength of 54,000 pounds per square inch and an elongation of 26.3 per cent. The strength appeared to increase with rise of temperature, until at 750 deg. the figure stood at 60,300 pounds, while above this temperature the strength decreased rapidly until at 1020 degrees it was only 26,000 pounds per square inch.

CHEMICAL SECTION

*Mica and the Mica Industry.

By George Wetmore Colles.†

[The subject is treated in eight principal captions: Mineralogy, geology, geographical distribution, history, mining, uses, statistics and conclusions. The treatment is industrial rather than theoretical or scientific, and aims at setting forth the present, past and probable future of mica-mining in this and other countries. The first instalment dealt with the characteristics of the various species of mica. The present part deals with the geology of the micas,—The Editor.]

II. GEOLOGY.

Micas of the perissad class (as above indicated), are found in or derived from igneous, that is to say, intrusive or metamorphic rocks. They are the commonest of minerals, common in the sense of being widely distributed, though constituting but a relatively small proportion of the rocks in which they occur. These micas constitute the most conspicuous element in granites, and in most schists and gneisses, as well as in that form of intrusive rock known as pegmatite.

The artiad micas, on the contrary, do not occur (unless possibly in minute crystals of the ferrous kinds) in igneous rocks, but are found associated principally with crystalline lime and magnesian rocks, such as calcite and pyroxene. The origin of these two classes will therefore be considered independently.

In addition to these sources of mica, it is a very common constituent of many fragmental rocks, ordinary quartz-sand, etc. Whenever a mica-bearing rock is eroded by water, particles of the mica which it contains are carried with it and deposited in beds somewhere in the course of the stream. Although mica is a heavy mineral (sp. gr. 2.6 to 3.2) its flaky nature causes it to be carried along or floated with an equal facility to lighter materials, such as sand, and when deposited with the latter in large quantities, the flakes falling naturally into a horizontal position, and the strata being afterwards consolidated, a schistose rock is formed, which easily splits by reason of the lack of cohesion between the mica plates.

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*Read by title. †Copyright, 1905, by George Wetmore Colles.

THE GRANITIC MICAS.

Such is doubtless the origin of most micaceous schists; but there are other rocks of a similar class and quality, which are to be classed rather as metamorphic, that is to say, rocks of a sedimentary or fragmental origin, but which, when deposited, contained no mica, and in which the mica has been developed by a process of slow crystallization under the continued application of heat. We pass thus gradually from the fragmental schists to gneiss, and go still further on the same lines from gneiss to granite, in which the bedding of the material has been entirely lost; and finally from granite to pegmatite, which latter may be described roughly as a kind of gigantic granite—a rock formed of the same materials but in very much larger crystals.*

Now, granite is a rock composed of three principal constituents, namely, mica, feldspar and quartz, and these minerals, as such, are not necessarily present in the rocks from which they have been formed. Their common occurrence, and more particularly that of mica, in rocks which have been altered by heat from rocks which did not contain them, is an evidence that, given the materials—alumina, potash, silica and water—and the necessary conditions, these materials will come together and crystallize out into mica of their own accord. That this is what happens, when a rock of sedimentary origin is altered to gneiss, is readily shown to be the case by the examination of a region of local metamorphism; that is, by examining the nature of the ground adjacent to a dike of igneous rock, for example, when what has been changed to gneiss close to the dike is, on following it back, found to pass gradually into sandstone, etc., the mica and other crystals making their appearance increasingly as we approach the dike.

Proceeding a step further from gneiss to granite, we have rock which results from a still further heating of the gneiss to at least a plastic condition, in which the materials have so rearranged themselves that the bedding is completely lost. The heat has been sufficiently continued and evenly maintained to permit the materials to group themselves into larger crystals.

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*There are several differences between granite and pegmatite besides the mere size of the crystals, that point to a difference in *kind* as well as one of degree. One of these is the different character of the mica crystals.

It is a well-understood principle that the size of the crystals formed increases with the slowness of the action, and this principle is clearly illustrated throughout the igneous rocks, and assists us in explaining the manner of their formation. The same rock, for instance, in a volcanic vent, which will on the surface form a close-grained, amorphous or aphanitic lava, will be found to pass downwardly into a more crystalline form until we reach the condition of granite.

The pegmatic dikes in which the commercial mica occurs are, as before stated, composed of the same three body-minerals as in granite; but the crystals are often enormous, weighing several thousand pounds. The mica in these dikes is always in the form of more or less perfect crystals, called by miners blocks or "books." The feldspar is also more or less perfectly crystallized, but much of it is massive, and the bulk of the quartz is also massive. It is deserving of note, further, that while quartz veins* are of common occurrence, and while dikes of feldspar and quartz occur together without the mica—in fact about as frequently as with it—the mica itself, which constitutes the least bulk of the vein, is never found without both the feldspar and quartz.

It is also important to note in this place that the mica crystals as taken from the dike, are of rough, opaque and irregular exterior, and have rounded ends and angles. The outermost plates, and the edges of all the plates, are valueless, and have obviously either (1) suffered alteration from their original form, or (2) never quite reached the constitution of mica, strictly speaking.

With these preliminary considerations we are in position to consider, first the age of the dikes, and afterward the origin of the mica.

Age and Origin of the Pegmatite Dikes.

The mica-bearing dikes in New Hampshire, North Carolina, South Dakota and India, and probably in all other places where

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*The net-work of coarse and fine quartz *veins* which commonly traverse the dikes and country rocks are merely an aqueous filling of cracks formed by the folding and faulting of the rocks, and must not be confounded with *dikes* of igneous origin.

mica has been mined, occur in rocks of the Archæan age, the first age known to geological history. The rocks of this age are not, however, either wholly or mainly igneous, but, like those of subsequent ages, are principally bedded or senimentary rocks, which were once deposited at the bottom of a body of water. All, or nearly all, the rocks of the Archæan series, so far as known, have undergone metamorphic action, and become more or less crystallized. Into and through these rocks, which themselves contain mica in large quantities, but in minute scales, have been injected the dikes in question and take the form of sheets more or less continuous and irregular, cutting across or between the strata which they intersect. Now, it does not follow, because these are found in Archæan rocks, that they have been formed in Archæan time, as it is clear that, if no reasons to the contrary exist, they might have been formed at any subsequent epoch; but I believe that such reasons do exist, and that they show quite clearly that these dikes were formed shortly after the formation of the rocks themselves, at least in the case of the North Carolina series, to which the following remarks have application more particularly, although I believe in a general way they will apply to other regions where mica dikes are found.

These dikes, generally speaking, follow the strike and dip of the country rock; that is to say, are interposed rather between the layers than across them, though frequently breaking from one to another, besides branching out and becoming divided, and being of very irregular width. A single outcrop may extend several hundred feet on the surface of the ground, and may be as much as 50 to 100 feet in width (still wider ones have been found), or may have any dimensions less than these. The outcrop being "nipped" at any point (that is, tapering down to nothing), may begin again a little further on or at one side of the point of nipping. (See Fig. 20.) The distribution of the mica in the vein is not uniform, nor is it entirely irregular. It has a tendency to gather into bunches, or in strings of crystals. It may be found ranged along either or both walls of the dike, or bunched in the recesses thereof, or in branches and pockets of the dike, or again, packed in bunches in the center at intervals. Fig. 17 illustrates some of these peculiarities.

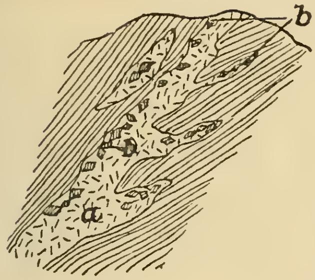

Fig. 17. Section of Point Pizzle (Cloudland) mine. *a*, dike; *b*, mica. (After Kerr.)

The influence of the wall rock on the material of the enclosed dike is often distinctly noticeable. Mica-bearing dikes predominate especially where they interpenetrate schists and micaceous gneisses; but not necessarily so, as good mica-bearing dikes also penetrate strata containing little mica. In India, however, this peculiarity seems to be very strongly brought out, and so much so that one writer on the subject assumes it as a proof of the aqueous rather than the igneous origin of the dikes.* The boundaries of the dikes are usually well defined and in close contact with the wall-rock, though a clay selvage has been observed at the juncture. This is undoubtedly formed by the decomposition of the dike-material through the action of water in the usual manner of feldspar. Fragments of wall rock are occasionally found in the dike, and Figure 18 is an example of a horse of wall rock running parallel to the dike, the only example known in North Carolina of this structure.

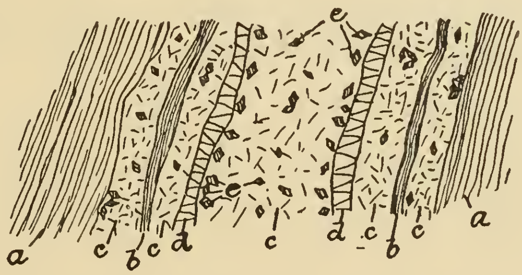

Fig. 18. Section in Silvers Mine (after Kerr). *a*, country rock; *b*, horse of same; *c*, dike material; *d*, quartz vein; *e*, mica.

In considering the origin of these dikes it seems to have been generally assumed that the dike-material was projected upwards while they lay in their present position. I cannot see any reason for adopting this view, while, on the contrary, there appear to me to be strong reasons for believing them to have been formed while the rocks were horizontally bedded. Moreover, with a few possible exceptions, there is nothing to show

*A, Mervyn Smith in "Mica Mining in Bengal, India." Trans. Inst. Min. and Met., Vol. vii, p. 170. This theory is referred to later. (See discussion on p. 282 *et seq.*

that the fissures, in which they lie, were ducts which led the material in a stream from some heated source below to the surface; but, on the contrary, they are distinctly of a *laccolithic* character; in other words, they were the mere filling of cracks which extended laterally from the source of molten material, probably ramifying from this source and ending in a *cul de sac.*

Figures 19 and 20 represent graphically the general manner in which the dikes may be supposed to have been formed.

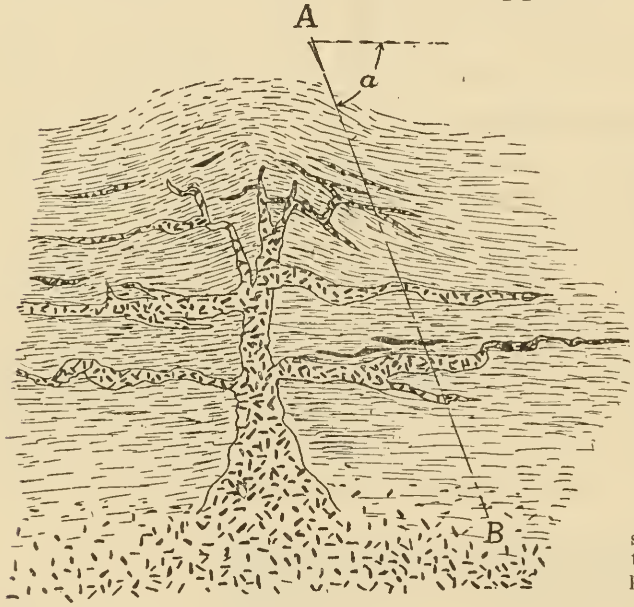

Fig. 19. Hypothetical section of laccolith of mica dikes.

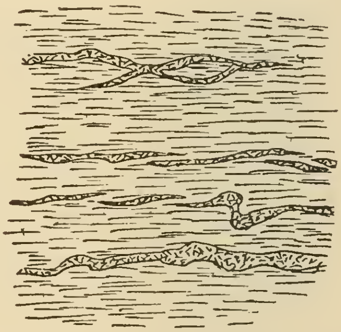

Fig. 20. Surface outcrop when strata of Fig. 19 have been tilted through angle a and denuded to plane A-B.

Figure 19 shows a vertical cross-section of a part of the bedded rocks and a column of fluid or semi-fluid rock-material injected upward into them by pressure from below, and naturally raising the strata above it. The rocks are supposed to be deeply buried under overlying strata, and the heat to increase downwardly until at their lower portion they become sufficiently fluid to be forced upwardly in the manner indicated, raising the overlying rocks. For the force to accomplish such an injection, we would only need to look as far as the difference in specific gravity between the solid and fused material, and the expansion of the water contained in the latter—I will not say *steam,* as is done by some writers, for it is clear that steam could hardly—at any rate did not—exist under this pressure and the comparatively low temperature which must be assumed. Whether the fissures were made by the pressure of the material which filled them or by some other agency, or by both acting to-

gether, is a question which need not here be answered. After the material filled the fissures an excessively slow cooling rate is demanded by the condition of the dikes, as we find them, by reason of the immense size of the crystals. Supposing, then, dikes to have been thus formed and cooled, and subsequently the rocks to have been tilted through an angle *a*, Fig. 19, and erosion taken place until the surface of the ground lies on the plane AB, the appearance of said surface would then be as shown in Fig. 20, which represents the dikes as we actually find them.

The reasons for the conclusions above adopted are as follows:

(1) The country rock shows a regional and not merely local metamorphism, as it would if it had been near the surface when the dikes were intruded, and such metamorphism were caused by the heat of the dike-material itself. In other words, the metamorphism of the rocks is comparatively uniform throughout the entire area under consideration. Such metamorphism implies that the rocks must have been buried very deeply in the earth, at least several miles below the surface. Now, that there has been an enormous denudation of the Archæan rocks,—greater, perhaps, than that of any subsequent series,—is clear when we consider that the rocks of all subsequent formations have been made from them. We must suppose, then, that the existing rocks were formerly overlaid by a thickness of several miles of the same system, and it is very improbable that much folding could have taken place before these subsequent rocks were laid down, or yet while they were very deeply buried, because we know that much folding has taken place since then, which, of course, tends to tilt the rocks always more steeply and never to return them to their horizontal position. The same holds good even if the strata overlying them were of a later age, for example, the Silurian or Carboniferous.*

2. The material of the dikes had no outlet to the surface, as it would have had if the rocks had been tilted (because the pressure would have been exerted to split a passage open instead of to raise the rocks); because (a) we find no deposits of material which would indicate such outflow; (b) the vein would have been banded, which it is not, or crystallized normal to the

surface, indicating a cooling from the exterior inwardly, which it is not; and (c) because the continued or interrupted flow through the fissure would have prevented the formation of any large crystals. With a few possible exceptions, like that illustrated in Fig. 18, the dikes are of a simple structure, that is to say, show that like conditions existed throughout, and no bands nor orientation of the crystals (unless it be that of the mica crystals *inter se*) can be observed.

3. To permit the slow rate of cooling demanded by the large-sized crystals and the other conditions just specified, the country rock must have been raised to a temperature approximating, if not equal, to that of the fused material, thus constituting a mass perhaps several miles thick, which would require centuries to cool down to the condition of complete solidification. This of itself indicates horizontal strata for the reason above indicated, viz., that the metamorphism took place before the tilting of the strata.

The aqueous theory of these dikes deserves mention here as it has been seriously put forward by at least one writer. The reasons given for this theory are as follows: (1) "in many places the veins die out in depth and in length;" (2) "the vein matter partakes of the quality of the including rock,—quartz, feldspar, and mica predominating, as the lode traverses rocks containing these minerals in excess;" (3) "the crystallization of the vein matter varies within very short distances, not being at all homogeneous as one would expect in an igneous dike. In places the crystals of mica are two feet long, eighteen inches wide and nine

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*From a consideration of the positions of the strata, J. D. Dana concludes that "no upturning took place over the Appalachian Mountains southeast (sic) of New England until the Carboniferous Age was approaching, or had reached its end."

A like conclusion is reached by J. A. Holmes, who has shown that the pegmatite dikes intersect the Archæan of Arizona, where it is cut through by the Colorado River in the Grand Canyon, coming up to the base of the Algonkian (the series next following the Archæan), which overlies these rocks, and consequently that the dikes were formed before the Algonkian period. In this case, however, the tilting of the rocks must have taken place during the Archæan itself, and consequently the intrusion of the dikes at a period long preceding even that comparatively early epoch.

inches thick. Within a few hundred feet on either side of this spot the mica books are small and worthless."*

Not only are the reasons so given to support this theory quite inadequate and inconclusive, but the theory is open to other objections which appear to me quite insuperable. Apparently it is based on the assumption of open fissures formed in the rock, into which ground waters carrying dissolved constituents of the country rock have flowed and evaporated, thus leaving behind the dissolved matter as a crystalline residue. To answer first the three reasons supposed to support the theory: (1) The fact that the veins die out in depth and length does not necessarily imply this theory more than another, as we have seen. (2) The influence of the substances of the wall-rocks can be explained equally well on the igneous theory; in fact such influence is commonly felt in igneous dikes. It is frequent for the materials of intrusive and intruded rocks to become interchanged through metamorphism,—not, however, that this has been the case here. Such influence is readily explained, more particularly where the wall rock is a friable mica schist or the like, on the assumption that the fissure produced by the fissuring forces was not a clean one, but that much of the rock-material was pulverized and mingled with the vein-material and subsequently dissolved therein and recrystallized. Besides, supposing the vein material to be merely melted wall-material from further down, it would naturally have a similar constitution. (3) That the constitution of an igneous magma should be not strictly homogeneous, but should vary within distances of a few hundred feet, is really no stranger than that an aqueous solution should do the same thing.

The most obvious objection to the aqueous theory is, that it presupposes fissures or voids in the rock which could hardly have existed. Either (1) such fissures must be formed while the rocks are still horizontal, or (2) after the rocks had been tilted, in which case they must have extended from the surface downward.The first assumption, in view of the great weight of overlying rock, is obviously untenable. The second is almost if not quite equally as untenable, by reason of the lateral pressure on the earth's crust which would close the fissures. Such

*A. Mervyn Smith, *loc. cit.*

fissures are indeed formed in the course of mountain-making upheavals but they are of a temporary nature, and are quickly filled with debris from the surface, which could not fail to show in the vein. Besides, as we have seen, the dikes have, in many cases at least, been formed before the rocks were tilted. I consider this reason alone conclusive against the aqueous theory. Further, however, it may be said that (1) the constituents of such veins, if formed, would be banded and would show a crystallization normal to the surface, and this as we have seen really never happens; (2) the water would evaporate too quickly to produce large crystals; (3) the mica portion of the vein-constituents is insoluble in water, and in fact in any other liquid, at surface temperatures and pressures. To suppose them to have dissolved out of the rocks and recrystallized by the action of water, is no more reasonable than to suppose that the mica had been conveyed there bodily. This fact also appears to me conclusive against the aqueous theory. In fact, the crystallization of mica, in the present state of our knowledge, implies the presence of heat.

Origin of the Mica.

Having thus determined the age and manner of formation of the dikes, it remains to consider how the mica was formed and reached its present position. Three views have been proposed: (1) that the mica crystals were formed in the fused rock-mass before the latter was injected into the fissures to form dikes; (2) that the mica existed separately as such in the fused mass at the time of intrusion, having been formed further down; and (3) that the mica, quartz and feldspar all existed together in a homogeneous solution both before and after the intrusion of the dike material, and that the several materials crystallized out one after the other in the same manner, as for example, salt crystallizes out as a result of mixing soda and hydrochloric acid; the several materials being brought together by chemical attraction in either case. That the third theory, or rather a modification of it, is the only rational one of the three can, I think, be readily shown to be the case.

First, however, we must consider which of the three principal materials of the dike reached the solid condition first. Under conditions as we know them in the laboratory, the feld-

spar has about the lowest and quartz the highest melting point of the three, the mica occupying an intermediate though somewhat variable position; but under conditions of high pressure and temperature, and added to these the elements of water, these conditions may be widely different. That water must have been present is to be taken for granted, both because it is difficult to assume a high enough temperature to have produced the effects without it, and also because it is present in the mica; as well as from the fact that steam is always given off in volcanic action.

The mica and feldspar are in fact both crystallized in a massive quartz matrix. The mica plates have left their marks both on the feldspar and on the quartz. It is clear that the mica could not have crystallized after the other two had solidified around it, therefore it is tolerably clear that the mica crystallized first, or at least concomitantly with the feldspar. We may assume that the feldspar and quartz together formed a vehicle for the mica. The crystalline form of the feldspar would seem to indicate that it separated out from the magma after the mica, leaving the quartz behind to solidify last. If the quartz still contained water (which would have made it more soluble) this has been subsequently driven off.

If the mica had been carried up in solid crystals mixed with the magma, we should here find it (1) all arranged on the hanging wall, to which it would have floated as soon as the magma came to rest, supposing it to have been lighter than the latter; or (2) it would have sunk to the bottom and we should find it all on the foot-wall of the dike, had it been heavier than the magma. Furthermore, it is utterly impossible that small branches of the dike could have been found packed full of mica crystals; in short, this theory is obviously untenable.

That mica may have existed as such in solution in the magma may well be admitted, but the question as to whether it existed in any special combination apart from the other elements, is about as futile as a like question with regard to all chemical solution. Suffice it to say that the arrangement of the crystals does not admit of any general theory, which does not presuppose that all the elements of the dike were uniformly mixed and tolerably homogeneous at the time they entered the fissures in which they cooled. Formed as they were from rocks

containing the same materials, and, indeed, the same minerals only in different form, they could not have recrystallized in larger crystals had they not been dissolved and recombined.

It has been shown that wherever the materials of mica are present in such a mixture, even though it be not fully fluid, they tend to be drawn together and to crystallize out as mica. The fact that chemical affinity exists sufficient to segregate them, even in a substantially solid rock, is shown by common local metamorphism, and is rather strikingly illustrated by the parallel case of crystallization or recrystallization of hard steel under long-continued vibration. In this case it requires a jarring movement to bring the molecules together; in the case where they are held in a partially or wholly melted state, for a sufficient length of time, chemical attraction alone seems necessary. The force that will explain the building up of a large mica crystal by the drawing together to one point of the elements of such a solution, seems absolutely identical with that causing a crystallization of any chemical substance from solution, more particularly if it be assumed that as the solution cools the mica becomes more and more insoluble therein.

That, moreover, the mica did so crystallize is plainly indicated by its local position in the dike, from its having, as aforesaid, a tendency to cling to one wall or to the other, or to cling together in aggregates precisely as in the case of other crystallization from solution, and the same reasoning pursued will explain equally the separation of the feldspar and quartz in great masses instead of in small particles as in other rocks.

Much has been said and somewhat has been written on a possible rule for finding the mica, and although miners themselves pretend to have rules and principles for finding it, it is pretty safe to state that no such rule exists, and that aside from the principle of crystallization which is alluded to, mica crystallized at random on one wall or the other, according to where chance happened to start the process. It was stated above that the dike material in the fused form was substantially homogeneous, but of course this does not necessarily apply to very extensive areas, and from place to place it would naturally vary in its contents of mica materials, thus giving rise to barren spots in the dike, and in some cases to dikes which were altogether free from mica; but the causes and order of such events would be as

difficult to define or regulate by rule as the movements of old Mother Earth herself.

The question as to what causes the rough, scaly exterior of mica crystals is one of considerable interest, and no doubt having an important bearing on the question of origin, but one which, so far as I know, has never been discussed. That it is not a result of secondary alteration or at any rate of the action of air and water penetrating from the surface, is, I think, all but certain. It has been shown that ordinary watering processes have little effect on ordinary muscovite, and if weathering were the cause, the effect would be limitd to mica dikes which have been partially disintegrated by weathering, and not extend into the solid rock itself. Moreover, there is no indication in the incasing matrix of any such alteration. Perhaps it has been due to the fact that when the mica was formed there was insufficient water taken up by the exterior portions to form perfect mica. This, however, is merely a speculation. There is, so far as I know, no published chemical analysis of the scaly exterior in comparison with the interior of the mica-blocks, and until we have such analysis, it is impossible to reach any definite conclusion.

As previously noted, the action of water penetrating through the material of the dike produces an alteration in the feldspathic contents, dissolving out the alkalies and leaving behind a hydrated aluminum silicate in the form of clay, while the mica and quartz are left untouched.

Occasional Minerals.

The pegmatite dikes, both of North Carolina and elsewhere, are noted for the number and variety of unusual minerals which they contain as accessories. A list of those occurring in the North Carolina dikes as prepared by W. C. Kerr, and corrected by F. A. Genth, is as follows:*

*Notwithstanding the revision, it seems very doubtful if this list is complete. *Rutile* (titanium dioxide) is a common inclusion in micas. *Pyrite* is almost always found in granitic rocks, though I do not remember having seen it in the Carolina dikes. Common *emerald* occurs in some mica dikes, as that of Villeneuve, Quebec. Probably also *ultramarines*. *Cassiterite* (tinstone) probably occurs here, as it certainly does in the dikes in South Dakota and elsewhere. *Kaolinite* is, of course, often present as a derived product. Spodumene (hiddenite), corundum, cyanite, and topaz also are mentioned as occurring with mica in North Carolina.

Albite	Magnetite
Allanite	Menaccanite
Amazon stone(?)	Monazite
Fluorapatite	Muscovite
Autunite	Phosphuranylite
Beryl	Pyrochlore
Columbite	Rogersite
Fergusonite	Samarskite
Fluorite	Thulite
Glassy feldspar(?)	Tourmaline
Garnet	Uraninite
Gummite	Uranocher
Hatchettolite	Uranotil
Limonite	Yttrogummite(?)

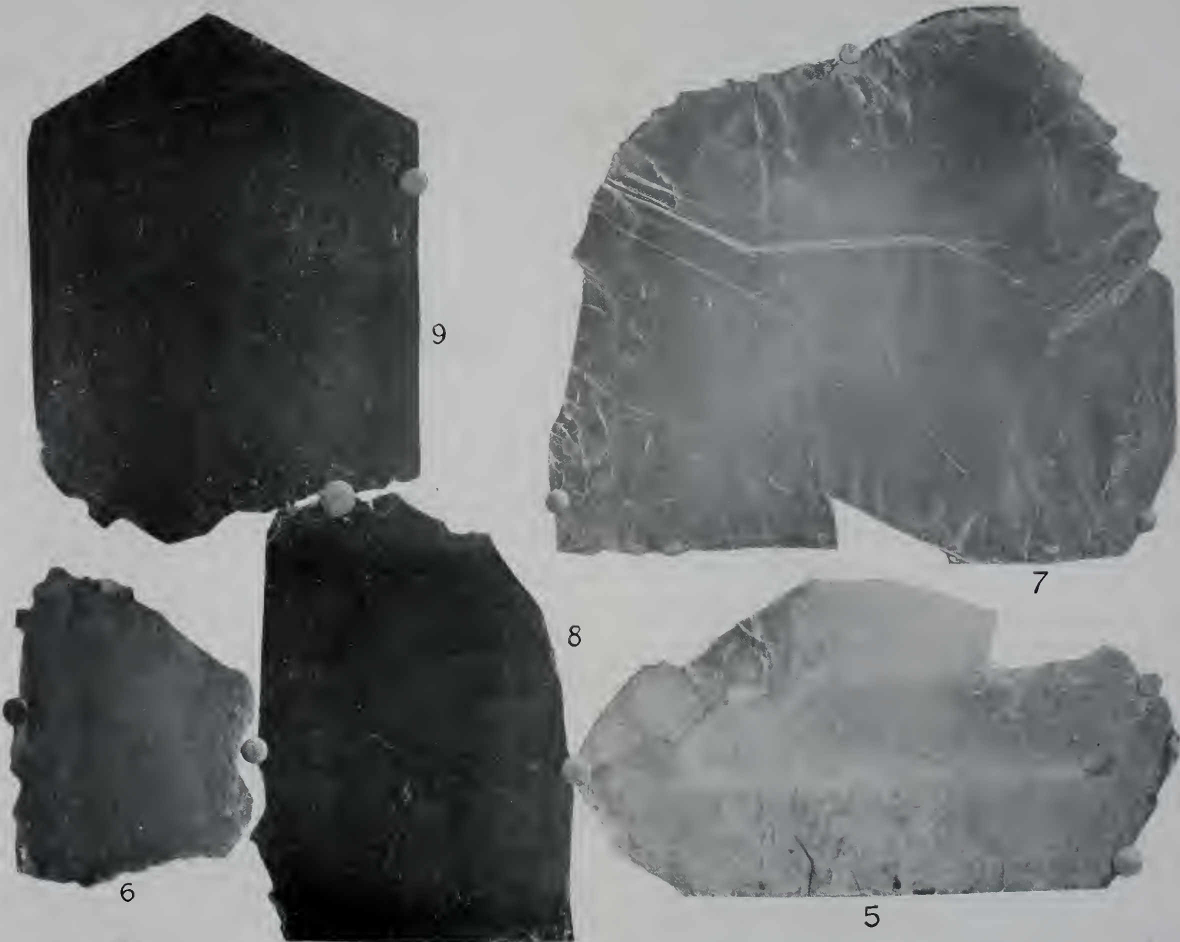
Many of these minerals are ores of the rare earths and elements, like cerium, thorium and lanthanum, etc., used in incandescent lamp mantels; uranium, used in the manufacture of fluorescent glass; niobium, tantalum and other rare metals, including, perhaps, the now famous radium; semi-precious gems, like beryl and tourmaline. These have formed from time to time a certain inconsiderable addition to the earnings of some of the mines. The question as to their source and meaning is certainly an interesting one, to which, however, so far as I know, no answer has ever been attempted.

THE PYROXENIC MICAS.

Whatever may be the origin of the micas in pyroxenic rocks, it is certain that it is very different from that of the micas just discussed. The difference is not only one of chemical composition, but also of geologic structure and character.

Magnesian micas are found associated with calcite (carbonate of lime) apatite (phosphate of lime), pyroxene (silicate of iron and magnesia), and hornblende (ditto). Although found in various parts of the earth's surface, they are unique in being known to occur in workable commercial deposits apparently only in the Laurentian of Canada.

The mode of occurrence of the Canadian mica deposits points to a more complicated mode of origin than that above assigned to the pegmatite likes. The magnesian micas do not



Figs. 5 and 6, Muscovite; Fig. 7, milgy amber mi a; Fig. 8, yellow-brown amber mica; Fig. 9, black mica (biotite). All from Florence County, Ontario, except Fig. 6, which is from Grafton, N. H. Figs. 7 and 8 are both from the Lacey mine. Note darker color of Fig. 6 as compared with Fig. 5, due to inferior transparency of New Hampshire product. Fig. 5 is spotty, due to green infiltrations between the leaves.

occur in normal pegmatite, although dikes of this material containing white mica are found in occasional deposits in their immediate neighborhood. The deposits of the magnesian micas and their associated minerals appear to be more in the nature of veins deposited through the principal agency of water, aided by some degree of heat. The country-rock consists principally of gneisses and metamorphosed and crystalline limestones. We find these country-rocks largely intersected by the veins of the associated mica-minerals, principally calcite and pyroxene, and these, as in the case of the pegmatite dikes, largely follow planes of the strata, but also cut across them both horizontally and vertically. The contacts between the vein material and the gneiss is often indefinite, indicating a widely extended impregnation of the latter by the former. These veins or instrusive masses appear to be true fissure veins in many respects, indicating that the filling material was not under pressure. (1) The veins are frequently banded, and successive fillings alternating as pyroxene, calcite, etc., may be indicated. (2) The apatite and mica deposits are found in irregular pockets in the pyroxene, and the segregation of mica in shoots is common. (3) Void spaces forming chimneys and druses containing free crystals are of common occurrence. These could hardly occur under conditions of external pressure unless we suppose the presence of large quantities of gas or vapor. The presence of hot gases, moreover, is indicated in some places by the burnt condition of the chimneys. The veins do not die out in length or in depth, but they extend as far down as mining has yet been carried, amounting to from 300 to 400 feet in Quebec.

The most important geological feature to note about these magnesian mica veins is that the mica occurs nearly always on or near the contact surface between the pyroxene and one of the other rocks, especially calcite or gneiss. Dr. R. W. Ells, of the Canadian Geological Survey, has classified these deposits into three principal heads:* (1) Deposits between the pyroxene dike and gneissic country-rock; (2) in pyroxene near the

*"Mica Deposits of Canada," by R. W. Ells, Bulletin C. G. S., 1904. A fourth class is given, defined as dikes of pyroxene cut by both calcite and pegmatite, but this variety does not seem to be either frequent or well defined, and is admitted by the author himself to be a form of class 2, hence it is omitted above.

contact of cross dikes of diorite or pegmatite (the mica of this class is pockety); (3) in pyroxene on and near a fissure plane. Though apparently inseparable from pyroxene to any great distance, the matrix of the crystals is often actually one of calcite of apatite, which is interpolated between the pyroxene and the country rock. The calcite and apatite do not always occur, as the pyroxene does, but the best mica appears to be usually found in the deposits containing these minerals—best both in quality and size.

From their nature, deposits of this class are very much more concentrated than in the case of the granitic micas. Instead of concentarted than in the case of the granitic micas. Instead of occurring in isolated crystals, it occurs in densely packed crystalline masses, which form a vein in themselves without much

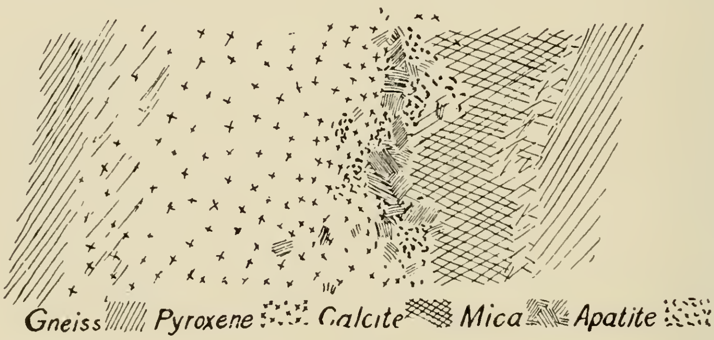


Fig. 21. Ideal section of Magnesian mica vein.

access of other material. These crystals are as a rule of small diameter and of very great length, but plates of immense size are common in some of the mines. These plates, like those of white mica, are frequently bent, twisted and flawed, but the reason appears to lie in the crowding of the crystals among themselves rather than in the bending and folding of the strata in which they occur. The crystals lie with their axes in all directions, haphazard, and without any observable arrangement; and the sides of the crystals, that is, the edges of the plates, are for the most part not rough and ragged as in the case of the granitic micas, but are smooth, clean and polished. As might be expected from the solid interpacking of the material, voids in the interspace are of frequent occurrence. (See Fig. 21.)

It is obvious that the contactual nature of the micas and their immediate association with pyroxene form the most important indices to the origin of the mica. Whether segregated from

the elements of pyroxene alone, or whether formed by a new chemical combination from these jointly with those of some other rock, it seems impossible to say with certainty, because an explanation that would do for one deposit would fail for another. The most probable theory seems to be that the mica is a surface crystallization upon the pyroxene and from materials contained in it while the latter was still in a plastic condition. That it could have been formed after the rocks solidified is clearly impossible.

Age of the Canadian Deposits.

The Laurentian hills, in which these deposits occur, belong not only to the Archæan age, but to the oldest recognized period of that age. It is generally held among geologists, following the original theory of J. D. Dana, that this portion of the earth's surface has been out of water nearly all the time since the strata were first raised, which raising is supposed to have taken place before the beginning of the Cambrian epoch. There are doubtless indications that this may have been the case, and also it may not be too much to state that proofs are lacking.*

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*In drawing his "Archæan Map of North America," Prof. Dana simply drew in the Archæan areas of the present day as land, and everything else as water, stating that these areas formed the nucleus of the continent; which forms a part of the argument for the semi-religious thesis on which his views of geology were based; and subsequently geologists seem to have simply adopted Dana's views. In other words, the continent began with the present Archæan areas and continued in a general way evolving from this as a base to its present extent. As all subsequent formations have been derived from the Archæan this necessarily supposes that the material which went to form all the other deposits of the continent, from the Cambrain to the Quaternary, were at one time heaped up on the present Archæan areas. So stated, the theory appears in its true light as nothing less than ridiculous. Besides, to suppose that the present Archæan areas constituted the first land is nothing less than impossible, for these rocks are stratified, and consequently, in the nature of fragmental rocks, were derived from *other* land, either by means of rivers or ocean currents, which other land must have existed before these Archæan areas were formed. Inasmuch, then, as other land than the present Archæan constituted the first land of the continent, and the nucleus has been changed at least once, we may as well admit that it has been changed a hundred times. We do not know what is under the earth more than a few thousand feet, and if, for example, some point in Arizona were subjected to a continuous raising and denudation for a sufficiently long time, washing away one formation after another until the Archæan was reached, it would offer a very similar condition to that of the Laurentian Hills, and no doubt ancient beaches, etc., would be found which would bear up the theory that this point formed the beginning or nucleus of the continent.

But the present area was, at all events, at one time covered with many thousand feet of superposed strata of *some* age. The question is, (1) were the mica deposits, etc., made during the Archæan age and prior to the general metamorphism of the rocks in which they occur; or (2) were they deposited in subsequent ages when overlain by rocks of later periods, and then metamorphized—being perhaps derived by infiltration from aqueous solutions bearing material from these latter rocks; or (3) have they been formed by aqueous deposits since the metamorphism of the rocks, and never undergone any metamorphic action? These questions are much more difficult to answer than the questions as to the origin of the granitic micas, and, in fact, a definite answer cannot yet be given. Certain considerations, however, point to the last of these three views as the most probable. The manner in which the veins intersect the strata of gneiss and each other, and the presence of chimneys and voids, appear to indicate with tolerable clearness that the strata had been metamorphized and upturned before the veins were formed. For the same reasons the veins were probably formed near the surface, and extended perhaps but a short distance (several thousand feet) below it. Expanding gases may have opened the rock-fissures and a heated magnesian-aqueous magma followed to fill them. This agrees tolerably well with the theory of Dr. R. W. Ells, of the Canadian Geological Survey, that the material was derived from igneous sources as submarine injections. This must have been prior to the laying down of the Cambrian and Silurian, which immediately overlie the Laurentian series and limit the exploitable area; for no mica dikes are found in any of these.

Relation of Mica Deposits to Archaean Age.

Existing *commercial* mica formations appear to be exclusively confined to the Archæan rocks—though there may be exceptions. We are naturally inclined to ask, Was there some peculiar geological condition acting in the Archæan, which produced these rocks, and which does not now exist? I believe there is no need for such a hypothesis. We know that mica in small crystals occurs in crystalline rocks of all ages, and that such crystals are produced naturally in these rocks wherever the materials

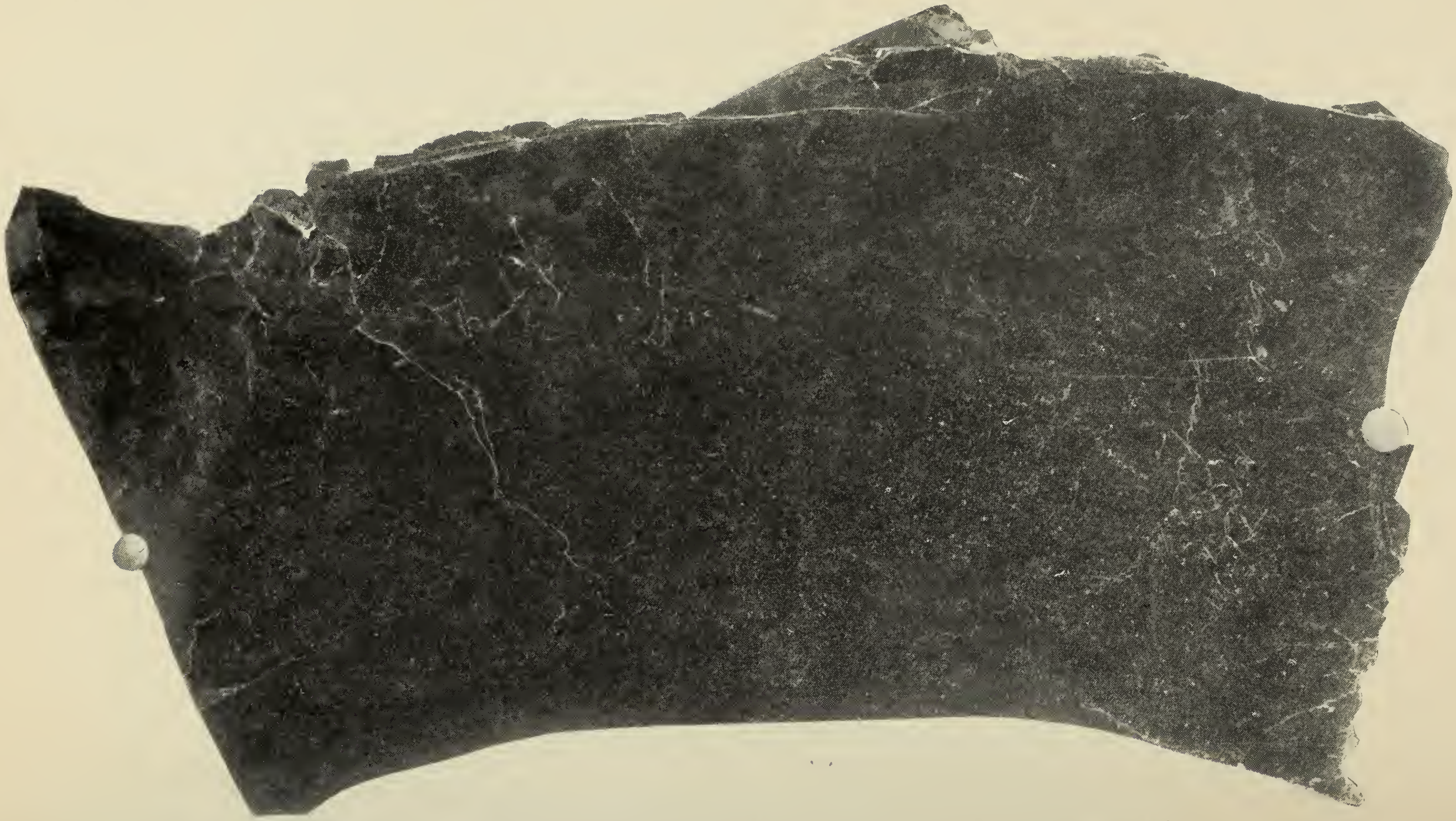

Fig. 22. Black mica (biotite) from Gracefield, Ottawa County, Que. The plate measures 20x9 in.

for its formation are at hand, and the heat is continuously maintained. We know that the Archæan rocks differ from all later rocks in being universally metamorphized; but this is obviously explainable in the same manner as the greater extent of metamorphism among the primary or secondary than among the tertiary rocks; namely, that they have been more deeply buried than others; and not by invoking an extraordinary terperature on the earth's surface in the earlier time.* As previously explained, the pegmatite dikes imply the burial of the rocks in which they occur beneath several, perhaps many miles of overlying strata, a condition which could have been attained only by the Archæan rocks; or, if attained by others which exist to-day beneath the earth's surface, the time has been insufficient to raise them and denude them sufficiently to expose the deposits. This does not, indeed, explain the Laurentian micas, unless we assume them also to have been formed at a great distance from the surface; but it should be remembered that these are the only deposits of magnesian micas of importance that have as yet been commercially worked, and that little as to their day or manner of origin can be certainly predicated at the present time.

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*The fact should be emphasized here, that the Archæan age was an age of land and water, of building up and of laying down, in every way similar to the present so far as concerns any evidence to the contrary, and was emphatically *not* an "age of fire," as it is frequently thought of as being. I have heard Archæan rocks talked of, by persons who ought to know better, as "plutonic," meaning rocks which originated through cooling from a state of incandescence at the time that the globe first solidified from this state. The stratified condition of the rocks shows emphatically that this is not the case. If there was an "age of fire," no evidence of it can be obtained from the rocks themselves, and it must have preceded the Archæan Age by at least as long a time as has elapsed since its close.

Another common assumption is that the Archæan preceded the origin of life on this planet, and it has been called the "Azoic," or lifeless age—because the Archæan rocks contain no recognizable fossils. No assumption could be more gratuitous. It would be, of course, a bootless task to search for fossils in granite, calcite and pyroxene, but fortunately there is abundant evidence for the existence of life of a varied and comparatively complex character in the Archæan.

(*To be continued*)

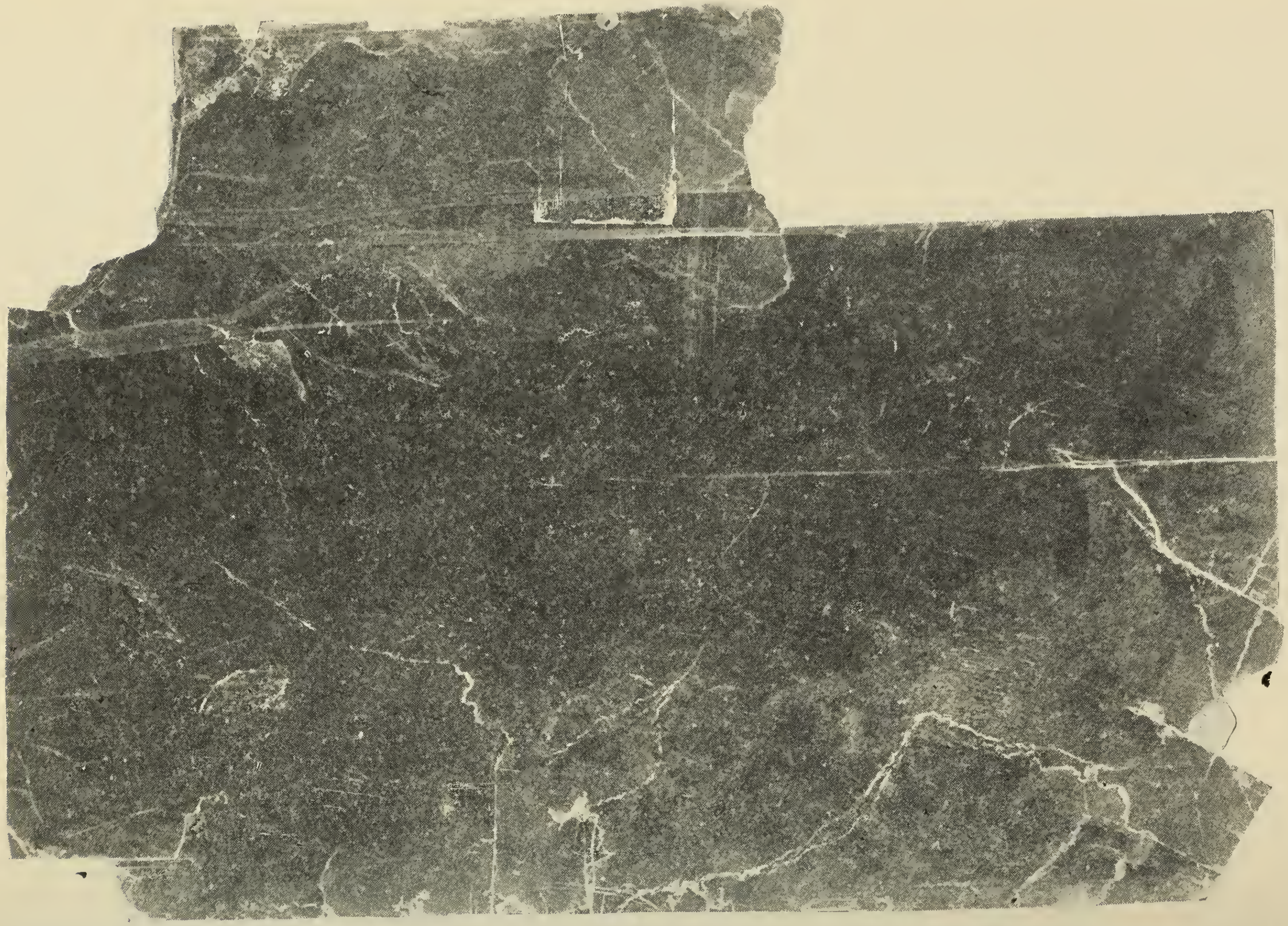

Fig. 23. Normal amber mica (mottled), from Lacey mine, Sydenham, Ontario. This plate measures 23x17 inches. The upper and lower edges are lines of natural ruling, hence the plate is but a fraction of the size of the entire crystal.

HEALING QUALITIES OF EGG MEMBRANE.

At a recent session of the Therapeutical Association of Paris, Doctor Amat lectured on the use of membrane of eggs in the treatment of wounds. He has observed for some time the good results of placing these membranes upon the surface of wounds, and reports two new cases, that of a young girl suffering from a burn on her foot, and a man, forty years old, with a large ulcer on his leg. Both wounds are in process of healing, and were covered with healthy granulations. The surgeon overspread them with six or eight pieces of the membrane of eggs, which was covered with tin foil and fastened with dry antiseptic bandages. After four days the bandages and tin foil were removed, and it was shown that the membrane of the egg had partly grown into the tissues and had caused the growing of a good skin. That the egg membrane had contributed much to the healing process was demonstrated in the further course of treatment. It seems, however, that the membrane does not always adhere. The process of cicatrization is not only hastened but the wound heals exceptionally well and leaves but few perceptible traces. As these membranes are procurable everywhere their use should attract more attention.—*Richard Guenther Consul-General, Frankfort, Germany, May 15, 1905.*

PREPARATION OF RAILWAY CROSS-TIES.

The *Revue Générale des Chemins de Fer* describes the preparation of cross-ties by the Compagnie de l'Ouest by means of the injection of creosote. Works for the purpose are established at Surdon in the department of Orme, about the center of the railway system. The yard occupies more than eight hectares. The ties, on arrival at the yard, are classified according to their comparative resistance to the penetration of creosote, and are piled up so as to dry by means of a free circulation of air. This requires from six months to a year, after which they are placed in hot-air driers for twenty-four hours and afterward in large hermetically sealed injection cylinders, heated by steam worms, under a pressure of two kilogrammes, which allows of maintaining a uniform temperature of 80 deg. C. for the creosote. A vacuum is produced in the cylinders, which are put in communication with the creosote vats. When filled with the liquid, an inside pressure of seven kilogrammes is caused by means of pumps for thirty-five or forty-five minutes. The annual production at Surdon is 297,000 cross-ties, and 200,000 posts, stakes and other pieces.—*Scientific American.*

THE DISPOSITION OF THE BOSTON "FRANKLIN FUND."

The Board of Aldermen of Boston, Mass., has formally accepted the offer of Andrew Carnegie of an endowment fund of $400,000 to be used for the maintenance of a trade school to be established by the Benjamin Franklin Fund, which is the accumulation of a bequest by that eminent American made a century ago. The condition of Mr. Carnegie's gift is that the institution be patterned after the Cooper Union, New York.

Stated Meeting, held Thursday, April 18th, 1905.

The Sanitary Protection of Water Supplies.

By Kenneth Allen.

Chief Engineer Water Department Atlantic City, N. J.

[Unsanitary conditions may be detected by analysis of water, by inspection of watershed or by mortality statistics. Knowledge of the life history of the typhoid germ and registration of vital statistics are important. Presumptive tests for B. Coli valuable.

Corrective treatment may be applied by the individual but should be applied to the entire supply. It may consist in: 1. Prevention of pollution; 2. Adoption of a pure supply; 3. Purification of an inferior supply. Control by Boards of Health, with Federal control as a last resort, is suggested. In any case ample power and funds should be provided. In selecting method of securing pure water with limited resources do not strive for ideal results in some detail at expense of greater general benefit.—The Editor.]

It is with a feeling of diffidence that I approach the subject of sanitation with relation to water supplies in a city where it has been uppermost in the minds of the people for a generation, where most eminent advice has been given with regard to the betterment of its own supply and where, finally, monumental works to alleviate the intolerable conditions of the past are approaching completion. But it is one of those matters concerning which eternal vigilance is the price of safety, and, moreover, it is one in which a marked development is taking place; and these are perhaps sufficient reasons for speaking on this subject to you to-night.

It has been said that the three great evils to mankind in the past have been war, pestilence and famine. In spite of the increased efficiency of modern arms and the recent activity in the East this great evil is becoming less and less. This, as pointed out by Bloch, is partly on account of the fearful destructiveness of scientific warfare from an economic point of view, but perhaps more on account of the rapid development of the humanitarian instincts since the first of the last century.

Famine, too, is a thing of the past in all civilized countries on accunt of the ample facilities for transport of supplies and the transfer of news, due to the use of steam and electricity. And, compared with the Middle Ages, modern society may be said to be free from the horrors of pestilence. With ordinarily decent modes of living those terrible scourges the plague and typhus have become practically extinct; with the general practice of

vaccination smallpox is not to be feared as in the past; more recently the prophylactic properties of specific serums are reducing the mortality due to diphtheria and other diseases and by the extermination of the stegomyia fasciata and anopheles mosquitoes the spread of yellow fever and malaria in Cuba and Panama is being controlled.

But in spite of all this progress in the prevention of disease the mortality from typhoid fever remains about 45* for each 10,000 inhabitants in the United States, and 52.8 in the case of Philadelphia; while it has been recognized for some years that this disease is due to a specific bacterium, that it is usually conveyed by drinking water, and that it is what is termed a "preventable" disease.

Growth in our knowledge of the causes of disease and its prevention have kept pace with growth in general sanitation. At the beginning of the 19th century conditions and customs were tolerated in English towns that to us seem inconceivable, while the simplest means of avoiding infection were neglected in those cases where the direct relation of filth to disease was not evident.

The case of the Broad Street pump, in London, whose clear, sparkling water caused in 1854 the deaths of 616 persons, is well known, yet even to-day it is hard to convince many that the danger in polluted water is generally invisible. Nevertheless, especially during the past thirty years, the early years of bacteriology, appreciation of the relation between water supply, filth, infection and disease has made rapid advances, and there is a marked demand for purer and safer supplies. What I wish to point out is the fact that the present attitude regarding this subject, as that regarding electricity, corporations, transportation, organized charity and prison reform, *is essentially modern—so* modern that as yet there is need of much educational work and much effort to utilize the knowledge we already possess.

The problem confronting the sanitarian is two-fold: the *detection of unsanitary conditions* and *their remedy*. In the matter of public water supplies we wish to avoid in particular ingredi-

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*Estimated at 46.27 by Dr. Osler in 1890, who also estimated a rate of 17.9 for England and Wales, 65.8 for Italy, 47 for Austria and 20.4 for Prussia.

ents prejudicial to health. Mineral poisons are seldom found but living organisms or their products may be the vehicles by which most dangerous diseases are transmitted, and it is the detection of these that most concerns the sanitarian. And right here it will generally be necessary for him to call to his aid the expert services of the chemist, the bacteriologist and the biologist.

But a few years ago, when it was found that the potability of a water could not be affirmed by its appearance, it was supposed that a chemical analysis would completely reveal its character.

This is true in a general way only. Gross pollution is readily detected by analysis and water of high chemical purity is seldom to be feared; but we now know that, in the dissemination of disease, bacteria, which are not discoverable by the methods of the chemist, play an essential roll. And while a public water supply should be free from sediment, color, objectionable tastes or odors, excessive amounts of iron, lime, magnesia or constituents that are capable of dissolving lead or other service pipes or fittings, the infection of a water supply by pathogenic bacteria, as the most important phase of the question, is the one I shall dwell upon in particular detail.

THE DETECTION OF UNSANITARY CONDITIONS.

Unsanitary conditions regarding a water supply may be detected by an examination of the water itself, by making a sanitary inspection of the watershed, or it may be revealed by the health and mortality statistics of the community served—especially those due to intestinal disorders such as diarrhœa, typhoid fever and cholera. The first of these complaints is not often fatal and is generally readily controlled by ordinary care in diet; cholera, although a most fatal disease, does not often obtain a foothold in well-regulated communities; but typhoid is always with us. It is, then, to the suppression of this disease more than any other that particular effort should be directed, and we may do this confident of success now that the cause of the disease and many of its characteristics are known.

Typhoid fever is the result of the lodgment and development of the typhoid bacillus on the walls of the intestinal canal to which it is conveyed by our food or drink; and while cases and

sometimes epidemics have been caused by infected shell fish, milk and other food stuffs that have become contaminated—perhaps by flies or by careless handling—the use of impure water is the most common source of the disease. It behooves us, then, to learn how our water supplies may become infected, how to detect such infection, what remedies to apply and what precautions to take to guard against further infection.

Prof. Sedgwick has said* that the germs "of typhoid fever are so few that all search for them by competent observers is usually in vain * * * . In comparison with the whole number of bacteria, those of typhoid fever are probably as rare as planets are among the stars, while, unlike the planets, they have no marked features of size or motion which enables them to be readily distinguished."

Although it may be said that the typhoid bacillus "has been found but by two or three competent observers so far in typhoid-producing natural waters"† we have been made somewhat familiar with its characteristics by recent studies by bacteriologists of cultures derived from infected sewage or dejecta.

From the standpoint of the sanitarian it is most important to ascertain the longevity of the typhoid bacillus under different conditions, especially in water, and the following are results that have been found by several observers:

Frankland experimented on the life of the typhoid bacterium in the polluted surface water of the Thames, the soft, peaty water of Lock Katrine and hard water from a deep well with the following results:

	Days when last bacterium was observed.		
	Thames.	L. Katrine.	Deep well.
When placed in raw water.........	9	19	33
Water sterilized by steam.........	32	51	20
Filtered water	11	39	11

Mr. George W. Fuller has found that the "typhoid bacterium continues to live in the waters of the Merrimac river at Lawrence, in greatly diminished numbers, for a period of at least twenty-four days.‡

Another authority states that "in sterilized water typhoid

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*Sources of typhoid fever in Pittsburgh—1898.

†Rep. John A. Amyot, M.D., San. Jour. Provincial Bd. Hlth., 1904.

‡International Public Health Congress—1893.

bacilli do not multiply, but perish in from one to three months. In water where there is much organic matter they may live longer, but the ordinary water bacteria seem to destroy them speedily."

Perhaps the most reliable data regarding the longevity of the typhoid bacillus have been obtained by Messrs. E. O. Jordon, H. L. Russell and F. R. Zeit[1] in a series of elaborate experiments made at the request of the Sanitary District of Chicago about a year ago. These are of particular interest from the fact that natural conditions or environment, including change of water, were employed by enclosing the organisms in permeable sacs of parchment or celloidin and immersing these at various points in Lake Michigan, the Chicago River, the Drainage Canal and the Illinois River. The soluble products of organisms existing in these waters were therefore brought into contact with the typhoid bacilli by osmosis while the bacilli themselves could not escape.*

These gentlemen found that under these conditions "the vast majority of typhoid bacilli * * * perished within three or four days," although "it is theoretically possible that specially resistant cells may occur which are able to withstand for a longer period the hostile influences evidently present in the water." And they further conclude:

1st. "That typhoid bacilli die out more readily in unsterilized water than in the same water sterilized by heat;" and

2d. "That when typhoid bacilli are introduced into unsterilized water containing little organic matter, their longevity is more prolonged than in water charged with considerable organic matter."

As to their survival during low temperatures, Professor Wm. T. Sedgwick says:†

"The latest and most trustworthy investigations on this subject do not support the idea that any considerable number of cases, even in a large city using a comparatively impure ice supply, can be traced to this source, and it is a remarkable and important fact that no epidemic or other excess of typhoid has ever yet been undisputably traced to infected ice.'"

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*Some doubt as to this last point has been recently raised by the results of experiments by W. R. Copeland at Columbus, Ohio. K. A.

†"Source of Typhoid Fever in Pittsburgh."—1898.

It appears, however, that this bacterium persists longer in cold weather than in summer.

As a rule deep-seated soils are sretile; but sewage bacteria have been found at considerable depths when forced through a porous soil by continuous dosing on the surface.

Mr. Fuller states that the typhoid bacillus has been found alive in the soil after five and a-half months, and that it has been found at a depth of nine and a-half feet.

Dr. Martin, of England, finds that "in certain virgin soils * * * the typhoid bacillus does not grow nor live under any condition of the soil, sterilized or unsterilized," but that "in cultivated soils, *i. e.* those containing organic matter, that have been sterilized, the bacillus lives for a prolonged period and spreads through the soil. If, however, the bacillus be added to a cultivated soil, sterilization of which has been omitted, the micro-organism cannot be obtained from such soil after twelve days or so."

Mr. George C. Whipple found, in examination of the sands of Long Island containing from 136,130 to 200,000 bacteria per c.c. at the surface, that at a depth of two feet there were but from 2,850 to 35,870; at a depth of 4 feet from 280 to 2,240, and at a depth of 7 feet from 0 to 170. "These results," he says, "indicate that below a depth of five feet the sand never contains more than a very small number of bacteria."

The longevity of this organism has a most important bearing on the transmission of typhoid by flowing water and has brought out elaborate arguments in testimony before the U. S. Supreme Court concerning the effect of Chicago's Drainage Canal on the water supply of St. Louis. Between the tendency of this organism to die out and the effect of dilution by the comparatively pure water of Lake Michigan it is argued that the waters of the lower Illinois and of the Mississippi at St. Louis are actually rendered safer and more pure than before.*

In fact, from a large number of analyses of the waters of the Illinois and Mississippi Rivers extending over the years 1897-1902, Prof. A. W. Palmer finds that "although the quan-

*Mr. John W. Alvord, assuming an average of 100,000 persons for every twenty deaths on the various drainage areas determines "effective populations contributing pollution" of 3,750,000 at Chicago, about 2,000,000 at Peoria after flowing five days and but 100,000 after flowing fourteen days.

tities or organic matters in the sewage now discharged into the Desplaines and Illinois Rivers are 30 per cent. greater than before, the proportions of organic matters contained in the waters discharged by the Illinois River into the Mississippi are very considerably smaller than they were prior to 1900; and that the decrease of the proportions is not a mere dilution, is shown by the fact that the actual quantities of organic matters discharged are less than they were formerly."*

According to Messrs. Zeit and Fütters:†

The Seine at 70 kilometers below Paris, the Oder 32 kilometers below Breslau, the Isar 33 kilometers below Munich and the Limmat 14 kilometers below Zurich, are each as pure as before entering these respective towns.

These gentlemen, after much experimental study, arrived at the following conclusions, the first of which, however, should be accepted with caution as not entirely in accord with the consensus of opinion among sanitarians, viz.:

"A seriously polluted water becomes pure again after flowing a certain distance. Pathogenic bacteria and sewage bacteria decrease as organic matter decreases. At the same time water bacteria increase. The presence of saprophytes hastens the removal of organic matter and the death of pathogenic bacteria.

"The quantitative bacteriological examination must give way to the qualitative, because a few infectious bacteria per c.c. constitute a more severe water pollution than a very great number of water bacteria."

According to Mr. Whipple, "The soil is the great repository of bacterial life, and every rainfall that washes the surface of the ground carries countless millions of bacteria into the streams. Hence, after every rain the number of bacteria in the water supply increases. The heavier the rainfall the larger in general will be the number of bacteria found. * * * Speaking generally, * * the numbers of bacteria in the Croton water measures the amount of surface wash into the stream, and hence the chance of infection."‡

Contrary to public opinion it will be seen that, so far as transmission of disease goes, the infection of a small rapidly-flowing

*Chemical Survey of the Waters of Illinois—1903.

†Sanitary Investig. of Ill. River. Ill. St. Bd. of Hlth., 1901.

‡Rep. Com. on Add. Water Supply for the City of New York, p. 378.

stream is more to be feared than that of a sluggish stream or reservoir. The great lakes receive untold polluting material, and yet furnish a wholesome water supply, except in the vicinity of towns. According to Whipple, "A water ten days after infection is perhaps one-sixth as likely to cause disease as that water one day after infection, while in one month it is perhaps one-fiftieth as great. The value of large storage reservoirs is thus evident."*

Moreover, as infecting material received by a small stream will be conveyed in a concentrated form, these require more vigilant inspection than large ones—other things being equal. The characteristics of large rivers are more permanent. In recent investigations into the filtration problem at New Orleans it was found that the Mississippi River at this point, although receiving the drainage from the vast population on its drainage area, was comparatively free from bacteria and organic pollution.

It is partly on account of the use of small streams, although more particularly from the careless location of wells and the lack of supervision over water supplies and drainage, that typhoid is often spoken of as a *rural* disease. And from its prevalence in the country on areas utilized, perhaps, for the collection of public water supplies, the need of efficient sanitary inspection of such areas is evident.

Conceding that typhoid may be derived from polluted oysters, dust containing the typhoid germ or polluted milk; that cases may be imported from other cities or induced by careless nursing, it remains a fact that the typhoid mortality of a town is perhaps the best single test of the quality of its water supply.

Why is it that Philadelphia, Pittsburgh, Allegheny, Troy, Albany and Washington have had typhoid rates in the past of from 65 to 110 per 100,000? And why is it that Boston, New York, St. Louis, Buffalo, Jersey City and Providence have had but 19 to 29 deaths per 100,000? while in Berlin, Hamburg, Munich, Dresden, Hanover, Leipsic and Cologne the mortality is but from 4.6 to 9 per 100,000? Unquestionably because the first-named cities have had polluted water supplies, the second set supplies from good natural streams or lakes,

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*Report on Quality of the Present Water Supplies of New York City—1904.

while the third set have supplies raised above suspicion. This opinion is confirmed when we come to study the epidemics of typhoid such as those at Plymouth and Butler in this State, Lowell and Lawrence in Massachusetts, Ithaca, N. Y., and many others, where there is abundant evidence of the contamination of the water supply by typhoid dejecta. In the first of these 1104 cases and 114 deaths were directly traced to one typhoid patient, although the water had first passed through three storage reservoirs having a combined capacity of 5,-000,000 gallons. Further confirmation is found in the relative typhoid mortality before and after the purification of the supply as has just been illustrated in your own city, Lawrence, Albany and Chicago. In Berlin, before 1883, the mortality from this cause was 1 in 9,000. After the introduction of filtration works the rate was reduced so that since 1893 it has been but 1 in 10,-000, or half as many as in New York. In 1876 it was 1 in 10,850 in Philadelphia, while now it is but 1 in 1890.

Yet another evidence that water is the chief cause of typhoid is mentioned by Dr. A. Seibert,* who attributes its prevalence in New York during warm weather—as has also been observed in the Prussian army—to the fact that more water is drunk at this time of the year, and that bacterial life is then more active and abundant.†

Turning now to the lives sacrificed annually by typhoid, these probably aggregate in the United States about 50,000; in New York 425; in Chicago (previous to 1900) 900; in Philadelphia (1890-1900) 600, while the loss in dollars and cents to the State of Connecticut alone in 1902 has been estimated at twenty-five million dollars. Mr. John W. Hill, of your filtration bureau, has estimated the annual loss from typhoid in the United States at $278,000,000.‡

It would seem only necessary to bring the intelligent business men of the community to a realization of such losses and the possibility of their control to ensure every safeguard over our water supplies.

It is most important that accurate statistics be kept of all

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*New York Medical Journal.

†The N. Y. Sun states that of 6,000 cases per annum in New York, half occur in the fall and one-fourth in the summer.

‡The Relation of Water to Typhoid Fever, 1898.

typhoid cases as well as deaths, for it is by noting an abnormal increase in these that we can best receive warning of an epidemic, and by properly interpreting a comparison with corresponding figures for other towns, that we may be in possession of one of the most valuable factors required in forming an estimate of the potability of a given supply. Dr. A. C. Abbott, Chief of the Philadelphia Bureau of Health, has said that "of the data relating to suspicious water supplies, those which are most trustworthy and constant in their indications are the regularly recorded vital statistics of the community using such water."

For this reason it is most unfortunate that the registration of vital statistics is not compulsory in this State although there are indications that this may be remedied before long.

The pollution of a water supply may be indicated by the examination of a sample of the water. Turbidity, color, odor and taste are sometimes indicative of its quality, but a chemical analysis is required to give quantitative results and to enable the expert to make a good guess as to the cause of pollution, if such be found, and whether it is recent or of long standing.*

Zeit and Fütterer state that "To establish the normal impurity of a river, the water level should be falling and no rains to increase the normal pollution * * * * Bacterial purification of a river can be judged by the gradual disappearance of pathogenic and sewage bacteria with falling water level.†

As a water used for drinking purposes should be judged when at its worst, however, samples should be taken both during a drought, or at least during a low stage of the stream, when impurities will be in a state of greater concentration, and immediately after a hard rain, when impurities will have been washed into the stream from the surface of the ground.

Pollution is indicated by the amount of nitrogenous matter

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*Mr. X. H. Goodnough states among numerous similar examples, (Report of Commission on Charles River Dam, 1903) "The waters of the Connecticut River * * * do not show any evidence to the senses of the pollution they receive after the sewage has entered the river at Holyoke, Chicopee, Springfield or West Springfield, excepting floating matters, chiefly from manufacturing wastes."

†Report to Ill. St. Bd. of Hlth. on Examinations of the Waters of the Ill. River, 1901.

in a sample of water, by the decomposable organic matter as indicated by the oxygen into which it will enter into combination and by the colorine above that found normally in the natural unpolluted streams of the neighborhood.*

None of these constituents is necessarily harmful, being rather *indicative* of pollution—past or present, vegetable or animal. As to the interpretation of the analysis, this should be done with great care and only considered final after confirmation by an expert. Even then the chemist may fail to discover the direct cause of disease—pathogenic bacteria, and it is necessary to turn to the bacteriologist for aid.

Bacteria are present in surface waters in countless numbers. The limit for a good drinking water has been placed at from 100 to 300 per c.c. Those ordinarily found are called saphrophytes, and are generally considered harmless, while others—pathogenic bacteria—are known to cause specific disease.**

Sewage may contain as many as thirty-five million per c.c.; rivers vary greatly, but may contain from several hundred to as many thousand; ordinary wells four or five hundred, while the waters of Lake Superior contain but from twenty to thirty per c.c. and artesian wells none.†

Now, although the dejecta of a typhoid patient may contain

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*Rough limits of these several constituents for a drinking water may be taken as the following in parts per million:

Chlorine	10	above normal
Albuminoid Ammonia	0.02	
Nitrates	0.05	
Nitrites	None	
Oxygen consumed	4	

**Bacteria are also classed as ærobic (normally requiring oxygen) and anærobic and as liquefying (those which liquefy solids) and non-liquefying bacteria. Of 440 varieties known, 196 are liquefying bacteria. In sewage there have been found, per cubic inch (cc?):

5	million	anærobic	liquefying bacteria
12	"	"	non-liquefying bacteria
8	"	ærobic	liquefying bacteria
77	"	"	non-liquefying bacteria

or about 100 million in all.

†As to their size it has been estimated that it would take about 53,000 to weigh a grain. The tvphoid bacillus, which was discovered by both Eberth and Koch but 25 years ago, is about $\frac{1}{50000}$ inch in thickness and several times as long.

as many as 2,000,000,000 typhoid bacilli per gram* it has been pointed out that by dispersion or death these are not readily found in even a grossly polluted water. Fortunately a more persistent bacterium universally found in the intestines of man and animals, known as the Bacillus Coli, affords an excellent means by which we may infer pollution from animal sources and hence danger as a conveyor of disease germs. Presumptive tests are therefore usually made for this bacterium. So universally is this found in surface waters, however, that perfectly good supplies may give positive tests with 10 c.c.†

Mr. Whipple suggests the following provisional scale by which the character of surface water may be judged according to the B. Coli it contains:

If found in	100	c.c.	the water	may	be	assumed as	safe
" "	10	c.c.	"	"	"	"	reasonably safe
" "	1	c.c.	"	"	"	"	questionable
" "	0.1	c.c.	"	"	"	"	probably unsafe.
" "	0.01	c.c.	"	"	"	"	unsafe

With regard to well waters the presence of this organism "is an almost infallible indication of the presence of contamination with surface water.‡

The identification of other forms of bacteria in the examination of water supplies is as a rule deemed superfluous and not attempted in this country, although it is recognized of much importance in studies of sewage purification.

Of several characteristic sewage bacteria it may be said, however, that *strepococci* survive in the soil but a short time; *B. Coli* disappear as a rule rapidly, but certain "strains" may survive for weeks or months, while *B. enteriditis sporogenes* may persist for long periods. The first two, therefore, indicate recent pollution—the latter, if alone, pollution in the past.**

In general, it may be said that chemical and bacterial examinations are mutually supporting, that the former are of greatest value in detecting conditions liable to cause offense to the senses, while bacterial examinations are of greatest value in determining the safety of a drinking water.

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*Hazen, Filtration of Public Water Supplies, 1898.

†George C. Whipple. "Quality of the Present supply of New York City."—1904.

‡Technology Quarterly, March, 1903.

**See report of Royal Com. on Sewage Disposal, 1905.

Examination of water supplies is regularly made now by most cities of importance. Chemical analyses are made by Baltimore, Brooklyn, Buffalo, Chicago, Newark and New York; bacterial examinations by Albany, Buffalo, Denver, Hartford, Lawrence, Newark and New York; and biological examinations by Albany, Brooklyn, Boston, Lynn, Pittsburgh, Buffalo and Wilkesbarre.

There remains a third way in which the contamination of a water supply may be detected, which consists in a sanitary survey, or at least an inspection, of the gathering area. Indeed, in all surface supplies a vigilant oversight of possible sources of contamination should be regularly maintained. Where the area drained is of great extent this may be limited to a careful examination of premises within a few miles of the reservoir or intake and a knowledge of the character of the drainage area—whether cultivated, wooded, rocky and hilly, or otherwise—the population and the general features of the sewerage systems of towns draining thereto. Although a water once contaminated cannot be considered safe even after flowing a great many miles, yet the further the source of contamination the less the danger: first, because in almost all natural streams the effect of dilution will be to decrease the proportion of impurities; secondly, organic matters will, by natural processes become mineralized and pathogenic bacteria die out, and thirdly, because by the sedimentation that is going on more or less at all times organic matter is entrained with the rest and carried to the bottom.

Baumeister has determined the impurities received by sewers (in Europe) to vary from 4.2 to 8.1, averaging 6.7, ounces per capita, about half of which is from human sources; and in order to compare the probable conditions of streams into which systems of sewers discharge he has deduced a formula for what he terms its "coefficient of pollution," which in English measures may be expressed as follows:

Let $E =$ the population on area drained
$C =$ proportion of population tributary to sewers.
$Q =$ discharge of stream in cubic feet per twenty-four hours.
$V =$ mean velocity of stream in feet per second.
$P =$ coefficient of pollution.

Then $P = \frac{Q\,V}{E(1+C)}$

He has used this in arriving at the relative pollution of various European rivers and various points in the same river.

Careful investigations have been made on the sanitary condition of watersheds now utilized for the supplies of Boston, New York, Philadelphia and Pittsburgh. In that of the Delaware watershed made by Mr. Rudolph Hering under the administration of Col. Ludlow, twenty years ago, a map was prepared containing a red dot for every 1000 persons, which illustrated in a very graphic way the relative density of population found in the valleys of the Schuylkill and Lehigh Rivers as compared with those found on the area draining to the Upper Delaware.

The following are the results obtained in several instances:

			Total Area Sq. Mi.	Popula'n per Sq. Mi.
Ohio River(Cincinnati)		1898	75,700	4.56
Croton	River	1904	338.8	52
Monongahela	"	1900	7,600	24
Allegheny	"	1900	11,400	24
Nashua	"	1894	118	58*
Mahoning Cr., (Youngstown, O)			967	77

As already stated, the character of a drainage area and that of the stream itself have great influence on the amount and character of its pollution. In a general way, however, it may be said that where the population exceeds 300 per square mile the water will be so contaminated that the supply will not be satisfactory,† while, with a population exceeding 125 per sq. mile, the water is open to suspicion.**

In the absence of available records of population we may assume for every 0.1 part per million of chlorine above the normal, a population of twenty-one persons per square mile of watershed‡—a relation calculated some years ago by Mr. F. P Stearns, now Chief Engineer of the Metropolitan Water Board of Boston.

The intimate relation between density of population and typhoid fever has been shown very clearly and graphically with reference to the Hudson River, by Messrs. Burr, Hering and Freeman in their recent report on a future supply for New

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*Exclusive of site of proposed reservoir.

†Rep. Mass. State Board of Health, 1890.

**Dr. S. W. Williston in Rep. Conn. State Board of Health.

‡Examination of Water Supplies Mass. St. Board of Health, 1890.

York by plotting the total population and deaths from typhoid as positive and negative ordinates, respectively, with corresponding abscissas in miles. The typhoid mortality on the drainage area is, therefore, an important factor in the contamination to be expected in a stream.

In a sanitary survey note should be taken of the character and volume of trade wastes, as from tanneries, wool and dye works, breweries, sugar refineries, paper mills, etc.; of the drainage from barn yards. cesspools, fertilized lands and swamps; especially in the vicinity of the intake.

In some cases deterioration of a supply is caused by deposits of organic matter—sludge, sawdust, etc.—in the bed of the stream or reservoir from which it is drawn. But such deposits, the inspector should remember, are not always cumulative, decomposition tending to balance the increment, so that a stable condition of such deposit is no proof that deposition is not constantly taking place. Several centuries ago the Thames was so clogged in this way that large vessels were unable to reach the city of London.

The investigations of Dr. George W. Soper of the possible sources of contamination of the Ithaca supply during the epidemic of 1903 is of interest in this connection as illustrating the grossly unsanitary conditions that can exist on the very outskirts of a University town of above the average character, imperilling the lives of the inhabitants. Of some 14,000 inhabitants 1350 were taken sick and 82 died within about three months. In repeated cases privies were noted draining directly to the water supply of the city. Had these premises been under competent inspection possibly the Water Company would have more fully realized in advance the terrible risks being taken.

The three chief sources of information from which we may form an intelligent opinion of a water supply are, then:

1. The typhoid rate among consumers.
2. Examination of the water itself.
3. Inspection of the watershed with reference to possible sources of pollution.

The first of these should always be watched, the second should be applied at such regular intervals as appear desirable, and the third is of especial value in cases where possible sources

of pollution—especially those of a temporary nature—may exist within several miles of the reservoir or intake. With full information from these three sources those in authority will be enabled to intelligently select and apply such measures to remedy the situation as are proper.

THE REMEDY FOR UNSANITARY CONDITIONS.

Corrective treatment in the case of a polluted water supply may be applied by the individual consumer. He may attach a Pasteur or Berkefeld filter to his faucet, which, if carefully attended to, will remove unwelcome bacteria. He may boil or distill the water, which is safer yet, and then, by adding drops of muriatic acid diluted to 10 per cent. strength and two grains bicarbonate of soda to each gallon, make it again palatable. Or, finally, he may sterilize it by contact with copper—a very simple remedy recently described by Prof. Henry Kraemer in the American Journal of Pharmacy, consisting merely in the immersion in the water of a piece of copper foil about 3½ inches square to each quart tobe purified for from six to eight hours.*

Prophylactic measures left to the option of the individual are always evaded by a large proportion of those most in need of them and are impracticable to enforce. The remedy must be applied on a large scale—to the water supply as a whole. In the remedy, as in the detection of unsanitary conditions, there are three general courses that may be pursued, viz.:

1. The prevention of pollution.
2. The adoption of a pure source of water supply.
3. Purification of an inferior supply.

The question of stream pollution is becoming a very pressing one in the thickly settled parts of this country as it has been for some time abroad. It is one requiring broad and judicial treatment. The questions of a legal and scientific nature that are involved cannot be safely left to popular opinion, even if free from bias. Experience would seem to indicate that responsibility in the preparation and enactment of laws and in their execution should be vested in a competent board or com-

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*Sterilization after infection has taken place has been tried successfully by Dr. J. E. Woodbridge by the administration of specific medicines and is of much interest but hardly pertinent to this discussion.

mission, but there is considerable diversity in the ways by which it is sought to control the pollution of water supplies in different states. This is, and should be, undertaken by those directly in charge of water works without dependence on outside aid. Every corporation supplying water to a community should satisfy itself as to its original quality and take measures to avoid any subsequent deterioration that may occur.

In the application of such measures not only sewage but storm water effluents should be diverted from the supply. The anomaly may be noted that, while the activity of its contained bacteria tends to purify water percolating to lower strata the percolation of a good water through a considerable distance of the top soil may cause its deterioration, and that long contact with surface moulds, as in overflowed swamps, is liable to injure a water; so that in constructing reservoirs the top soil is often removed at considerable expense; that very shallow reservoirs, exposing a large surface to both the underlying soil and the heating effect of the sun, are to be avoided, while very deep reservoirs are also objectionable, as the deeper portions cannot avail of the sunlight and air for their purification.

If the area is not too great a regular patrol of the watershed and examination of samples should be maintained, as is done in Brooklyn, Providence and Baltimore.

Unfortunately there are water works where these matters, not being compulsory, are neglected. In this case the value of a competent Health Board becomes apparent, having power to formulate and execute such measures, however drastic, as are required for the public safety.

There is a very great diversity in the composition and authority granted health officials in this country, and much legislation governing these matters is antiquated. In spite of marked differences the State Boards of Health of Massachusetts, Connecticut, New York, New Jersey and Ohio may perhaps be selected as those taking the lead to-day in securing effective results. In Massachusetts, New York and Ohio the local authorities are required to consult with and may receive advice from the State Board, while in the latter, at least, such advice may be mandatory. In the above States and New Jersey and Connecticut the Board is expected to investigate all new supplies and in the case of Ohio this is mandatory.

It is believed that in minor matters the local health officers, or, at most, these and the water works officials by coöperation, will be able to secure proper conditions if given adequate authority. But in matters so vitally related as the sanitary conditions on a watershed and the health of a city's population there should be some central authority in control of both; and this generally takes the form of a State Board of Health, which, as has been remarked, has proven very satisfactory in several States.

In those cases where a supply is taken from a stream heading in or flowing to another State, new complications arise, and so serious may these become that a great city like New York is forced to abandon as a source of supply the one recommended by Mr. John R. Freeman) as that having the greatest advantages—Ten-Mile River in Connecticut—from fear of legislation.

The following opinion rendered on this point by the Committee on Legislation to the Engineering Committee of the Merchants' Association of New York in their comprehensive investigation of the question about five years ago is of interest:*

"In our opinion the City of New York has no right to divert the flow of the Ten-Mile River from the State of Connecticut, nor to divert the flow of the Rampo River from the State of New Jersey, and in case of such diversion of the Ten-Mile River a lower riparian owner on the river in Connecticut could enjoin the proposed diversion in an action either in the United States Courts or in the Courts of New York State."

Also, "We are of opinion that the City of New York cannot acquire any power of preserving drainage basins from pollution in the State of New Jersey, except by purchase."

It is a question whether the difficulties in the case might not have been overcome by compensation to riparian owners or else resort to the Federal Courts if a strong sentiment in favor of this plan had existed among those in authority.

Nevertheless this suggests the desirability of providing interstate regulation in order that an important city may avail itself, if necessary, of far-lying water supplies, though naturally

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*The Water Supply of New York, 1900, pp. 452, 476.

tributary to other nearby towns without resort to litigation. The inadequacy of artificial political boundaries is to a certain extent recognized in Great Britain, where officials in control of matters pertaining to stream pollution are given jurisdiction over certain drainage areas instead of a county or other arbitrary area. In the matter of water supplies this plan may in certain cases fail to be quite perfect because areas draining to surface streams and those draining to underground supplies may be far from identical. In a general way, however, jurisdiction extending over drainage areas would appear most feasible and desirable; and in order to adjust questions arising where this area lies in two or more States it is evident that, unless unconstitutional, general control should be vested in some central authority.

In discussing this matter Mr. J. S. Haring has said:* "The only way to make the purification of water supplies effective is to first prevent, by Federal laws, the pollution of rivers and streams. Too many of our rivers are in the jurisdiction of more than one state to make the state control of these matters effective. * * * Only a general law, irrespective of State or city, can prevent effectually what will be in a few years, if it is not in some places already, an evil of great magnitude."

Interstate legislation would fail to overcome difficulties promptly and without friction.

It is suggested that, inasmuch as the U. S. Geological Survey contains a most efficient body of engineers, who have already done a large amount of valuable work in studies pertaining to hydrology, stream flow, stream pollution and artesian well supplies, and is now taking up extensive constructive work in connection with irrigation, it would provide admirably the central authority sought; while interstate disputes could be referred by the Survey to the Federal courts, and matters concerning local pollution left, as at present, to state or local boards of health.

For the application of such a system of control some plan such as the following, suggested several years ago,† might be adopted. This provided:

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*Trans. Am. Soc. C. E., Dec., 1899.

†Trans. Am. Soc. C. E., Dec., 1899.

First, that all streams should be classified according to their permissible contamination as follows:

Class I. Streams far from populous centers and not likely to be used for manufacturing or domestic purposes.

Class II. Streams likely to be used for other than domestic purposes.

Class III. Streams likely to be used for domestic purposes.

And *second*, a responsible officer should then be selected who should supervise and control all sources of pollution throughout the drainage area of every stream in which pollution is restricted by law.

The Survey or the officer in charge should, according to some well-considered plan, fix the limits of contamination in each case. It should also act as referee in questions relating to the appropriation of water supplies by different municipalities so as to secure the most efficient and equitable results, including those relating to the rights to underground supplies.

For condemnation of water rights lying outside the district in which the town or corporation seeking it is located, power would have to be obtained from the central authority.

The present Royal Commission on Sewage Disposal has had this question of the rights to natural supplies referred to it, and has suggested placing all necessary powers with proposed Rivers Boards, each Board to have jurisdiction over a group of drainage areas.

It may be said here that Speaker Nixon of the New York State Assembly has recently proposed a plan quite similar to that mentioned, allotting certain definite areas to each city in its search for water; while Governor Higgins suggests a State Commission to have jurisdiction over all water supplies, their apportionment and protection.

Whether power is vested in a special commission, a Health Board, or otherwise, it should be granted ample authority with funds to enable it to carry out its provisions effectively. It should be brought into close relations with its local agents, and these, in turn, should coöperate so as to secure the best results.

Referring to this State, which has suffered in the past from typhoid in both epidemic and endemic form, the Engineering News says "to put matters plainly (Pennsylvania) is well known among sanitarians to be notably backward in all mat-

ters concerning the protection of the public health" and this is attributed, not to the character of its officers, but to want of liberality in the legislature in granting adequate power to the State Board of Health, to local authorities and to water companies.*

According to Dr. Chapin, of Providence, it is desirable that the township should constitute the unit of sanitary control; that where, is in New England and Ohio, the township is well developed sanitary control is most successful; but that where this is weak—more dependent upon the county organization—as in Pennsylvania and the South—sanitary control is apt to be feeble and ineffective.

As to the personnel of the controlling body I quite agree with Prof. Sedgwick, who says: "The appointment of an engineer of distinction to membership in the State Board of Health (of Massachusetts) * * * in 1886 marked a new epoch in sanitary administration and has been followed by the happiest results. Other States have since followed the example of Massachusetts and with uniform advantage. * * * A good board of health should be very carefully chosen, should include in its membership one or more expert physician, at least one good engineer, and one good business man. Nothing less will answer for any progressive city in which health and decency are rated at their full value."

A reasonable control over the pollution of natural water supplies may be secured by invoking the common law, but statutory legislation is necessary to ensure purity sufficient for domestic purposes. Some of the more usual and important statutory laws prohibit the direct fouling of a supply by excrementicious or other decomposing organic matter, the discharge therein of sewage or other foul liquors, presence of privies, stables, manure heaps, cemeteries, etc., within a certain distance of the shore, or bathing in the waters of a stream or lake used for a water supply. Thorough disinfection of all discharges from those suffering from typhoid on the watershed should be required. Lack of this simple measure is no doubt the cause not only of much typhoid derived from drinking water, but of a considerable dissemination of the disease by

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*The State Board of Health has, since writing this, been reorganized with enlarged power, promising effective results in the future.

means of flies and dust in the rural districts; and each additional case there is an additional menace to the water supply.

Quite as important but more difficult to control is the dissemination of typhoid by those who have the disease in so light a form that they are not confined to bed, by the many cases that are not recognized as typhoid or are incorrectly diagnosed, and by convalescents who may unconsciously continue to spread the germs for many weeks after recovery.*

Attention should be directed to the water served in railroad trains. Unfortunately many towns are supplied with water that is positively dangerous to use. If the tanks in a train are filled in such a town travelers over many miles of territory may unwittingly place their lives in jeopardy by drinking it, and if sickness ensues the cause may never be suspected.

To provide the greatest protection to surface supplies some cities have gone so far as to buy up entire watersheds at great cost. In England, Manchester has secured 11,000 acres in this way, Liverpool has obtained authority to buy 22,000 acres and Birmingham 45,000. In Scotland, Glasgow has secured an agreement from the landowners that on 20,000 acres no leases shall be made for building purposes, while nearer at home, Baltimore has been considering the question of acquiring the watershed of its supply from the Gunpowder River.

But aside from legislative control much may be done by those in charge of water supplies by securing possession of and fencing in marginal areas of streams and reservoirs; diverting or even purifying storm water effluents (which are sometimes very foul), by providing and maintaining a suitable depth in reservoirs, by removing vegetation from the water and its shores, draining swamps on the watershed, removing muddy deposits from the bottom and by providing ample storage.

Surface waters undergo a marked improvement in storage under proper conditions, as impurities settle out and bacteria—especially pathogenic bacteria—diminish rapidly in number. As an illustration examinations of the Croton supply have shown an average reduction in bacteria in passing through the Central Park reservoirs of 45 per cent., while a further reduc-

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*172 million germs per c.c. have been found in the urine of a typhoid convalescent. See Petruschky in *Centralblatt fur Bakteriologie,* 1898.

tion of 29 per cent. takes place in the mains before reaching City Hall Square. The reduction found in the numbers of Bacilli Coli was even more marked.*

To prevent pollution, then we should seek the aid of the State through legislation and Boards of Health and those in direct charge of water supplies should take such measures as will not only prevent deterioration of such water after taken over into their hands, but, if possible, improve its quality.

With increasing density of population it becomes impracticable to avoid such contamination of surface supplies that they are unfit for domestic purposes. At such a time a stream of Class III (as proposed) would be placed in Class II, and towns depending thereon for a supply would be forced to one of two courses of action—either to seek some new and unpolluted source or to adopt some method of purifying the existing source; and it is believed that the time will come when all large cities will be forced to accept one of these alternatives. Consequently the development of ground water supplies will be more actively and scientifically carried out than heretofore. Already they are utilized to a considerable extent along the coastal plain between New York and Florida and in the Mississippi Valley. The difficulty of securing an artesian supply increases rapidly with its extent so that, although Brooklyn, Camden, Savannah, Galveston, Memphis and other towns obtain a great part of their supply in this way, it is in smaller towns that we find its greatest development. Serious objections sometimes met with are excess of iron, requiring its removal, as at Red Bank, N. J.; excess of soda, which discolors starch so that the water is unsuitable for culinary and laundry purposes, as at Charleston; excess of carbonic acid, by which lead service pipes are attacked, making tin-lined pipe necessary, as at Atlantic City, and a decrease in capacity frequently occurring from the clogging of the strainers. These may all be of so serious a nature as to render recourse to a distant surface supply preferable.

London proposes a water supply from Wales, and Liverpool, Manchester, Glasgow, Boston and New York have gone many miles to secure satisfactory surface supplies.

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*Rep. of Com. on Add'l Water Supply, 1904, p. 380.

A pure natural source is always to be desired, but failing in these there remains the possibility of purifying a polluted supply, usually by filtration. Within the last fifteen years filtration has been placed on a correct scientific basis and is generally accepted as safe and satisfactory if only the works are properly designed and operated.

While Europe has taken the lead in the introduction of filtration, we have probably surpassed her in excellence of design in our most recent works, and in magnitude those of Philadelphia will head the world's list. The adoption of filtration by Albany, Jersey City, Philadelphia, Pittsburgh, New Orleans and Louisville would be a sufficient guarantee of its efficiency if its results in reducing typhoid were not already known.

As alternatives there are boiling, distillation, æration, sedimentation, treatment with ozone and with sulphate of copper. The first two of these are not applicable to a city's supply on account of cost. Either sedimentation æriation—at one time in use here for the Schuylkill water—may improve the appearance and taste, but will not make a polluted water safe. There are several ozone processes, one of which has been in use by the city of New York in sterilizing sewage effluents on one or two of the Croton watersheds for a number of years. It is believed to do this effectively, but that its applicability in any given case will depend on the cost.

The very simple and inexpensive method of sterilization by the use of copper sulphate, suggested by Messrs. Moore and Kellerman, of the Department of Agriculture, and applied with success at Baltimore and elsewhere appears to be of particular value when used judiciously to remove contamination of a temporary character—either for offensive algæ or bacterial impurity. Its effects are marked and rapid. Dr. Moore cites a case* where "a spring, which was accidentally polluted, and which gave rise to over fifty cases of typhoid in less than a week (in which) the use of copper sulphate completely sterilized the water, and it was possible to continue using the spring within five hours."

One part to ten thousand parts of water, it is said, will destroy typhoid and cholera organisms in three to four hours,

*Eng. News, Feb. 9, 1905.

while one part in two million is generally sufficient. Algæ are destroyed by one part of the salt dissolved in from 100,000 parts of water in the case of Beggiatoa to twenty-five million parts in the case of Spirogyra.

Some very noteworthy results were obtained from its use in the polluted water of the Scioto River, supplying Columbus, Ohio.

Previous to treatment the colon bacillus was rarely absent from the water. From August 19th till December 30th, 1904, daily tests showed the samples to be free from this organism. January 5th, owing to alarm caused by the newspapers, treatment was discontinued. The consequent result as shown by the following tabular statement is strong testimony to the value of this method of treatment—at least as a temporary expedient—for the sterilization of an infected water:*

June,............	Water not treated	24
July,............	" " "	33
August,..........	" treated after the 19th	52
September,.......	" "	16
October,.........	" "	16
November,.......	" "	8
December,.......	" "	4†
January,..........	" not treated after the 5th	91
February,........	" "	376
To March 27,........	" "	279

So far, the Massachusetts State Board of Health has failed to recommend this method for general application, probably through fear that by carelessness so large an amount of copper might be used as to be prejudicial to health, and for this reason it has been recently unfavorably reported in connection with the supply of New York City.‡

To decide whether to adopt a new supply or to improve the

*Copper as an Algicide and Disinfectant in Water Supplies, Bulletin 76, Bureau of Plant Industry, 1905.

†Seventeen cases reported, but only four used city water.

More recent investigations indicate limits to the efficiency of this treatment, depending on temperature, quality of water, etc. K. A.

‡"If this process be carefully conducted such growths (of algæ) may be safely prevented in this way, but this Commission is decidedly opposed to the use of copper sulphate in the Croton supply, because, remaining in the water, if carelessly introduced, it might endanger the health of consumers. The report of Messrs. Hazen and Whipple contains similar conclusions."

Report on Filtering the Croton Water. Burr-Hering-Freeman, January 16th, 1905.

present one is often a serious question, and one that usually requires the services of the expert engineer. If the present source is not seriously contaminated, and if an artesian supply is available, there is the choice between purification of the former, the development of a ground water supply or of securing a new surface supply. Either may be entirely satisfactory as to quality, and it is probable that a comparative estimate will eliminate one or possibly two from the question. While a surface supply may be said to be always in need of inspection, this is no less of a filter plant; and although artesian wells be considered the safest of all, yet these have been known to receive serious pollution by hidden channels tapping contaminated surface water. It is noticable that while English towns generally depend on protected surface supplies, in Germany filtration is general and in France there is a marked tendency to secure underground supplies. We cannot always secure the ideal supply but must do the best under existing circumstances.

It may be said that no amount of dilution will make a stream once contaminated absolutely safe for drinking purposes; but we must bear in mind that all surface supplies are open to this criticism and, while the trend of public opinion is setting strongly toward filtered or underground supplies it will necessarily be many years before we can hope even to approximate such ideal conditions. We should, however, throw such safeguards about our surface supplies as will ensure the greatest practicable protection. In striving toward our ideals it is wise to consider the cost of each and then secure the greatest possible good with our available funds, leaving if necessary their absolute fulfillment to future generations. In the meantime we need not allow our ideals to fade or be lowered. While placing matters of greatest moment on a monetary basis—if you will—this way of securing the greatest good to the greatest number is, after all, both the scientific one and good common sense; and if a town with but $10,000 to spare can save more lives by providing a pest house or by introducing sewers than by perfecting its water supply, I would say build the pest house or sewers first by all means, and defer the desired improvements to the water supply. It is a business question—a matter of estimate.

DISCUSSION.

Dr. Henry Leffmann:—The many difficult problems that confront the municipal hydraulic engineers have been so well presented in the paper that further discussion is unnecessary. I desire to express strongly my approval of the author's endorsement of the value of chemical analysis of water intended for drinking purposes. When, about a quarter of a century ago, bacteriology took a sudden lurch into prominence, it was claimed that it would set aside chemical analysis. Koch said that such analysis is mere ethics. Naturally, it was thought that water-borne diseases are most likely to be due to minute organisms, the detection of which would be possible and sufficient. It soon appeared, however, that these organisms are very elusive, and, after many mistakes and some untruthfulness, bacteriologists are prepared to admit that the most important water-borne disease germ, that of typhoid fever, is practically not discoverable in ordinary waters. For the valuation of well and spring waters, chemical analysis is still essential. The data, chlorine, nitrates and nitrites give us information as to where the water has been and how long ago, points of great sanitary moment. I have long regarded the analysis, bacteriologic or chemical, of surface waters as of little practical value. It seems that each community must learn the lesson for itself, that unfiltered surface water that has been collected or has flowed through even a sparsely-settled district, is unfit for drinking purposes. In discussing the biology of the typhoid bacillus, it must be borne in mind that the researches are made with organisms that have been obtained from human viscera or discharges and not from water. I think that great caution should be observed in applying the biologic data obtained in this way to practical problems in water sanitation.

ARTIFICIAL SILK.

In the Consular Reports issued by the Department of State there has recently appeared an interesting note on the production of artificial silk by Mr. Richard Guenther, Consul-General at Frankfort, Germany, from which the following extract is made:

"For more than one hundred and fifty years efforts have been made to find a cheap substitute for genuine silk. At last cellulose has been found to be suitable for producing brilliant threads of silk-like appearance. The best

kind for the purpose is carded cotton, which was used by Count Hilairede Chardonnet, the first manufacturer of large quantities of artificial silk.

German chemists, among them Dr. Lehner, of Augsburg, also have solved the problem of making artificial silk. The chief difference between the processes of Chardonnet and Lehner is that the collodion from which the product is made is of a different character, and that in the process of Chardonnet the collodion is spun dry. Dr. Lehner spins his collodion wet and then lets it dry.

The associated factories of artificial silk of Frankfort-on-the-Main, comprising two factories in Germany and two in Switzerland, which have a community of interest with the Chardonnet factory at Besancon, in France, use the process of Chardonnet and Lehner. There is also a company at Elberfeld under the name 'Vereinigte Glanzstoff-Fabriken in Elberfeld,' which owns several factories in Germany and uses the processes of Dr. H. Pauly, Dr. M. Femery, J. Urban, and Dr. E. Bronnert. The last process differs from the other decidedly. Cellulose is dissolved in ammoniated oxide of copper and is then directly separated from this solution by means of an acid in the form of threads.

In order to arrive at a conclusion as to how far artificial silk can replace natural silk in the manufacture of silk goods, it is necessary to compare the physical and chemical qualities of the natural and artificial product. Under the microscope all artificial silks differ from the natural in their greater thicknesses. Tussah silk alone resembles artificial silk. Artificial silks, without exception, possess the quality of at once distending largely in water, which increases their thickness one-third to one-half, while natural silk does not distend perceptibly. This distending seems to be the reason that artificial silk, in a wet state, loses so much in firmness. The artificial silk manufactured by the two associations named shows qualities which come very close to those of natural silk and excels it in some respects.

The product is of an even white color, of a silky touch, and when pressed together has even some of the characteristic crackle of genuine silk, the so-called silky cry. It greatly excels natural silk in brilliancy. The chief use of artificial silk is in the passementerie industry. For passementerie goods and for trimmings it has proven so suitable that for such purposes it is even preferred to natural silk. For embroidering it is the ideal material; its high luster and adaptability to the form of the embroidery add a most brilliant look to such work. In the manufacture of straw hats artificial silk takes the place of straw. The hats made of it excel the ordinary straw hats in brilliancy. A separate branch is that of imitating human hair, called 'meteor,' made of artificial silk. Such imitation hair is as soft as the natural growth and cannot be distinguished from it; it is, furthermore, cleaner and cheaper. The price of natural human hair is often twenty-five times as high as the artificial article, besides the latter is not as heavy as the former. Artificial silk finds to-day an increasing market even in the silk-producing countries."

Book Notices.

Die Darstellung des Zinks auf elektrolytischem Wege. Von. Dr.-ing. Emil Guenther, Hûetten-Ingenieur, Aachen. Mit 59 in den Text gedruckten Abbildungen. (8 vo. pp. xii + 243). Halle a. S. Druck und Verlag von Wilhelm Knapp. 1904. (Price, 10 marks.)

The foregoing volume constitutes the sixteenth of the series of Monographs of Applied Electricity issued by this publisher, nearly all of which have received notice in the *Journal.*

The profitable production of electrolytic zinc has thus far proven to be a most troublesome problem to solve, and much more study and experiment will be required before it is satisfactorily solved. This volume here noticed will be found most useful in giving the investigating reader a complete resumé of the processes thus far proposed for the solution of the zinc problem, and of the results actually accomplished. The profitable solution of this problem would be one of the most important economic achievements in the field of metallurgy. W.

PUBLICATIONS RECEIVED.

Hydrology of the State of New York. By George F. Raiter (New York State Museum, John M. Clarke, Director. Bulletin 85. Economic Geology 12.) Albany: New York State Education Dept. 1905. 8vo., pp. 902. (Price, $1.50.)

Locomotive Testing Plant at the Louisiana Purchase Exposition, St. Louis, Mo. 1904. (Penna. Railroad Co.)

Schiff and Wasser. J. F. Becker, Schiffbautechnisches Bureau, Hamburg. 1905.

Report of a Fire, Sand and Water Test made upon a 20x22 foot span, hollow tile, grooved arch floor, constructed by the National Fireproof Company at Pittsburgh, Pa. By Ira H. Woolson, M. E. (Price, 25 cts.)

Renold Roller Chain. Booklet No. 54, 1905. Link Belt Engineering Co., Philadelphia 12 pages, illustrations, 8vo.

Armour Institute of Technology Year Book for 1905-1906. Chicago, Armour Institute of Technology Press, 1905. 195 pages, portrait, plan, 8vo.

Geological Survey of Kentucky. Charles J. Norwood, Director. Bulletin No. 1. Preliminary part. The Oil and Gas Sands of Kentucky, by J. B. Holing, Lexington, Survey 1904. 233 pages, illustrations plates, maps, quarto.

Proceedings of the Nineteenth Annual Meeting of the Conference of State and Provincial Boards of Health of North America, Washington, D. C., June 3 and 4, 1904. Providence: Snow & Farnham, 1904. 78 pages, 8vo.

School of Industrial Art of the Pennsylvania Museum. Circular of the School of Applied Art. Twenty-ninth season, 1905-6, Philadelphia. 56 pages, 8vo.

Concrete Steel. A treatise on the theory and practice of reinforced concrete construction. By W. Noble Twelvetrees. With numerous illustrations, designs and tables. 8 vo. pp. xii, 218. Whittaker & Co., London and New York. 1905. (Price, 6 shillings.)

The use of reinforced concrete has, within recent years, worked something of a revolution in engineering construction. This development has received its most active and successful impulse in this country, and it is accordingly a notable circumstance that one of the few contributions relating to the subject should come to us from the press of an English publisher.

W.

Franklin Institute.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 20th, 1905.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 20th, 1905.

PRESIDENT JOHN BERKINBINE in the chair.

Present, 43 members and visitors.

Additions to membership since last report, 13.

Mr. Lindon W. Bates, of New York, described and illustrated with the aid of models several modifications of the present plans for the construction of the Panama Canal, for which he claimed special advantages. (The communication will appear in the *Journal.*)

Mr. Andrew Wright Crawford and Mr. Frank Miles Day, representing the organizations allied for the acquisition of a comprehensive park system for Philadelphia, presented some interesting data with lantern photographs, exhibiting the present status of the work.

The President expressed the thanks of the meeting to the speakers ot the evening, and adjourned the meeting.

WM. H. WAHL, *Secretary.*

Committee on Science and the Arts.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 6th, 1905.)

MR. SAMUEL SARTAIN in the chair.

Present, nine members.

The following reports were presented and passed first reading:

(No. 2339.) *The Walter Switch.* Dr. B. Walter.

(No. 2366.) *Fuel Saving Furnace and Method.* The Fuel Saving Co., Utica, N. Y.

These reports were held under advisement until the next stated meeting.

The resignation of Mr. Daniel Eppelsheimer, Jr., as a member of the Cimmittee, was presented and accepted, with a vote of regret.

On motion of Mr. L. E. Levy, the Chairman was authorized to appoint a special committee to prepare a memorial of the late John Carbutt, onetime member of the Committee.

WM. H. WAHL, *Secretary.*

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CHEMICAL SECTION.

(Continued from Vol. clx, p. 295.)

*Mica and the Mica Industry.

BY GEORGE WETMORE COLLES.†

[The subject is treated in eight principal captions: Mineralogy, geology, geographical distribution, history, mining, uses, statistics and conclusions. The treatment is industrial rather than theoretical or scientific, and aims at setting forth the present, past and probable future of mica-mining in this and other countries. The first instalment dealt with the characteristics of the various species of mica, the second with the geology, and the present one with the geographical distribution, history, mining and milling and the uses of the micas.—THE EDITOR.]

III. GEOGRAPHICAL DISTRIBUTION.

Mica of the granitic varieties is, as previously mentioned, found in every country, almost in every district of any size, in the world, but commercial deposits are necessarily localized. In this review only commercial deposits will be considered.

At the present time three countries supply practically the entire output of the world, namely, India, Canada and the United

*Read by title.

States. No deposits of commercial importance are found in Europe, if we except some that have been found in Norway, but which, however, I believe to be too much honeycombed with intrusions to be of value, and at all events are not being worked; and the deposits of lepidolite or lithia mica in Bohemia, which are mined and smelted as lithia ore.* Brazil has within the last few years contributed slightly to the supply, but the output in this direction is probably sporadic and intermittent. Mica deposits, which could be utilized in default of others nearer the point of utilization, have been found in many of the newer countries, as for instance South Africa, Borneo, and the Philippine Islands, and it is not doubted that these and many other countries might become producers, if the sources now productive were to fail. But the abundance of the supply produced by the three countries mentioned would seem to shut out any new sources for a long while to come, as there is no question that these, especially India, can meet any demand for the mineral that is likely to arise for many years.

THE GRANITIC MICAS.

Large deposits of this class are found in very many countries in all parts of the world varying from an excellent quality downward. Wherever Archæan areas exist mica deposits are likely to be found, and these are invariably in dikes or veins cutting through country rock.

United States.

The Appalachian system, from Maine to Alabama, has been the principal source of production in this country, but numerous fine deposits have been found in various parts of the Rocky Mountain system, also, which may prove of greater importance as that section of the country grows in population and wealth.

Alabama.—Mica of good quality has been reported in the northwestern part of Randolph and adjacent parts of Cleburn and Clay counties, near Pinetucky, and thence the mica area

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The Bohemian lepidolite has none of the physical characteristics of mica which make it valuable, as it is not found in laminated crystals, but in cryptocrystalline masses. It is mica in a chemical sense only, and is may be questioned whether it should be termed mica at all.

extends southwest as far as Chilton county, all in the northwestern part of the State. None of these deposits have been worked, however, and cannot be mined profitably at present owing to distance from the railroad.

California.—Ledidolite deposits of the massive variety have been found near Pala in San Diego county at the extreme south of the State, and have been known and worked since about 1899. Their product is bought by Schieffelin & Company, of New York, for the manufacture of lithia. In 1901, lodes of white mica were found in the Piru mining district on Piru and Lockwood Creeks, Ventura county, known as the Barton Mica Mines, about fifty miles from Los Angeles and fifty-eight miles from Bakersfield, in Kern county. The mica is of rather mediocre quality.

Colorado.—Mica deposits exist in this State along the line of the Rockies, as in Fremont and Park counties, in the central portion of the State. Companies have been formed to operate them, but little if any mica has been actually produced.

Connecticut.—Lepidolite deposits are found in this State.

Georgia.—The mica dikes of the Appalachian extend into the extreme northwestern portion of this State but have not been worked.

Idaho.—A district known as the Robinson Mining District, in Latah county, about eighteen miles from the Northern Pacific Railway, was exploited in 1895, since which time increasing quantities of mica have been taken out. Mica is found in a pegmatic dike averaging six feet wide and which has been traced for over a mile. Crystals containing plates twenty-two inches by twenty-six inches have been taken out. In 1900 the product was about 1500 pounds of cut mica. It is notable that this is one of the few places in the world where mica has been mined in a systematic modern fashion. An adit 600 feet long has been driven to the lode, and a 500 foot raise. The cost of mining is stated at $5.00 per ton—presumably of rough and not trimmed or cut mica. Of course this gives no adequate idea of the actual cost either per ton of rock mined or per ton of finished product.

Maine.—White mica deposits have long been known to exist in Oxford County on the western edge of this State, especially around Paris. At Mount Mica, near that town, are found

mica dikes containing many tourmalines. Lepidolite is also found. Companies have been formed from time to time to exploit these deposits, but without commercial success. At Buckfield, East Woodstock and Rumford, all in the same county, the dikes are found.

Nevada.—Mica was discovered in Lincoln county in 1897, and sheets as large as 9x10 inches have been taken out. The deposits are worked from time to time on a small scale.

New Hampshire.—This State, up to 1869, was the principal and only commercial source of supply for mica in the country. The mica district extends through the western portion of the State from about the central to the southwest extremity, in Grafton, Sutherland and Cheshire counties. Mica has also been mined at Danbury, in Merrimac county, just south of the Grafton county line. The most important mines for many years were the Ruggles at Valencia and Palermo, the first of which was opened in 1803, and furnished for many years the bulk of the country's supply. Some $8,000,000 worth of mica has been taken from this mine, but it has now been closed for some years, partly owing to litigation, and partly no doubt to the declining values of the product. When the North Carolina district began to be exploited, in 1869, the knell of the New Hampshire industry was sounded. The product of New Hampshire fell off constantly, and for the last fifteen years the mines have been operated in only a fitful fashion. The development of the electrical industries, which rendered salable some of the small-sized mica, and the rise of the ground-mica industry, have alone prevented an absolute cessation of mica mining in this State. Most of the product has been shipped from Bristol, Canaan, Grafton, Rumney and Warren, in Grafton county, Danbury in Merrimac, and Alstead in Cheshire county.

New Jersey.—Near Bloomingdale, Passaic county, in the Blue Ridge Mountains, in the extreme northern portion of the State, mica deposits have been discovered, but an attempt at working them has not met with success.

New Mexico.—In the Cribbensville district, in the north-central portion of the State, not far from the Colorado line, there are mica deposits, which were worked on a small scale for several years, in the early nineties, but this has been abandoned.

New York.—In Westchester county, near New York City, there are coarse granites containing crystals of small size, and mistaken attempts have been made to work them, of course, however, without success.

North Carolina.—This State is now the most important domestic source of mica, and is likely to remain so for many years to come. At the present time it produces some 60 to 80 per cent. of the total output. No deposits yet found have produced superior "water-mica" for stove-glazing purposes, and it is doubtful whether any have equaled it. Of course mica of poor quality is found in North Carolina as elsewhere, and mica of many shades and varieties. Mica lodes are found in all the western counties, but the mica district proper is nearly limited to the strip running southwest and bounded by the Tennessee State line (Great Smoky Mountains) on the west, and the Blue Ridge on the east, and in this district the most important deposits are found in Mitchell, Yancey and McDowell counties. The history of mica mining in this district is given at length in a later section. The principal mines now operated in Yancey county, are the Ray, Westall, Joe Gibbs, Young and Bailey Mountain, and in Mitchell county the Cloudland—formerly Point Pizzle—Deake, Flat Rock and Mart Wiseman. Only a few of these are operated continuously, however. The last-named is one of the most famous both for rare minerals and also for large-sized crystals of mica, a single block of A-mica from this mine measuring six feet by three feet, and weighing about a ton.* The old Silvers mine (so called from the original prospects for silver), from which at least $30,000 worth of first quality mica has been taken, is not now being worked. Bakersville, the county seat of Mitchell county, is the local center for the mica business of that county, whence the mica formerly was transported by team to Marion, in McDowelll county, some twenty-eight miles away; and all of the Yancey county product went to Marion. Within a few years, however, a long-projected railroad down the Toe River has been put in and the product is now brought to the railroad, thus saving a large amount of hauling.

South Carolina.—The Appalachian dikes are found in the

*William B. Phillips, *loc. cit.*

western portion of this State, as in the adjacent States, but have not been worked.

South Dakota.—Mica of commercial value was found in the Black Hills region of this State and Wyoming in the early nineties, and the deposits have been worked to a small but continually increasing extent up to the present time, notwithstanding the fact that the sizes are small and the quality of less value than the eastern mica. The principal district of exploitation lies on French Creek about six miles east of Custer City. The New York Mine, near Custer, is the principal one in this district. Further north, near Deadwood, Lawrence county, there are other mines, of which the Lost Bonanza is the most important producer. The Crown and Daly mines were opened in 1902. Most of these properties are owned by capital from Chicago and the Middle West. The South Dakota district is noted for the occurrence with the mica of spodumene. Cassiterite is also found in the mica dikes, and unsuccessful attempts have been made to mine it for tin.

Utah.—A deposit was opened in Salt Lake county in 1897, but no sheet mica of any value was reported.

Virginia.—Some mica credited to North Carolina has been produced from time to time in this State. The deposits lie principally in the southwestern portion of the State, west of the Blue Ridge. There has, I believe, been no production from this State during the last few years.

Washington.—A deposit was discovered and exploited in 1897 at Chelan Falls, Okanagan county, but the size was small, and it is not thought this can be successfully exploited, even assuming good transportation facilities.

Wyoming.—A little mica has come from the Black Hills region near the South Dakota boundary, but the principal mines are across the state line.

As will be seen, the only producing districts of importance to-day are in New Hampshire, North Carolina, South Dakota and Idaho, and of these New Hampshire will propably soon drop from the ranks. The future of South Dakota is doubtful, notwithstanding its present comparatively large production. The Idaho district is believed to have a possible future, and the North Carolina certainly remains to-day, and for aught that has

been yet found, is likely to remain for the future the principal producing State.

Canada.

There exist deposits of granitic mica in the neighborhood of the magnesian deposits of Ontario and Western Quebec; and these deposits are worked to a certain extent, notwithstanding they are of but mediocre value. The principal constituent of value in these dikes is the feldspar, which is worked for use in pottery. The really valuable white mica mines of Atlantic Canada lie in the region of the Saguenay River and Lake St. John, in Eastern Quebec.

Of the Ontario deposits there is one in Frontenac county, a specimen from which is shown in Fig. 6. In Ottawa county, Quebec, about sixteen miles north of Ottawa City, there is a dike containing lepidolite of good quality associated with green and opalescent feldspar and green and rose tourmalines.

The white mica mine most worked in this country is that at Villeneuve, twenty miles from Buckingham, which was worked by the British and Canadian Mining Company, Ltd., from 1884 to 1888, producing an annual average output of 9,000 pounds of cut sheet mica, which was nearly all consumed by the domestic market. Uraninite has been taken from this mine. This mine has not been worked for some years.

In the Saguenay River district, the principal deposits are in the canton of Bergeronnes and the adjacent cantons of Tadoussac and Escoumains on the Gulf of St. Lawrence; and also on the south side of the Saguenay, around the Upper Canard River. None of these mines has been worked to any great extent. The district suffers somewhat from lack of transportation facilities.

At Lake St. John and 250 miles to the north at the source of the Peribonca are likewise deposits apparently of very good quality.

On the north coast of the Gulf of St. Lawrence, 400 miles below the Saguenay at the mouth of the river Watshehoo there are some small islands containing large pegmatite veins offering mica prospects, but although well situated for operation, the deposits are poor.

Newfoundland has furnished samples of mica to the United

States, and there is no doubt that it is to be found there, but like all the minerals of that island, it remains unexploited.

In Western Ontario mica is reported from the Sudbury district, in Cleland and Gladman townships, and about twenty miles north of Lake Nipissing. Further west, on the border of Manitoba, in Rainy Lake county, white mica is abundant in several localities, notably on Falcon and Big Islands, and on Sabaskong Bay and on Rainy Lake.

The most important white mica deposits are probably those of Northern British Columbia, at and near Tête Jaune Cache, on the Canoe River, some 215 miles north of Kamloops, but these are so far from railway transportation as to place their exploitation practically out of the question for the present.

Dr. Robert Bell, of the Canadian Geological Survey, reports a good quality of mica from Hudson Strait, as well as from the Labrador coast, no definite information as to localities being given.

Mexico.

A deposit was exploited in 1898 to 1901 near Villa Corona, in Durango Province, North Central Mexico. There does not, however, seem any likelihood of the development of mica mining in that country. Mexico imports considerable mica from Europe.

Brazil.

For some years past mines have been exploited in the States of Minas Geraes, Bahia and Goyaz, which lie adjacent to one another in Eastern Brazil. The principal mines are in the State of Minas Geraes, not far from Rio Janeiro. These deposits are in pegmatite dikes, which run parallel to the Cayama and Popgais Mountains. Only two mines, Fonseca and Coronel Seraphino, are worked regularly, the last named yielding ruby mica. Small quantities of this product have come direct to New York, but the majority is exported to Europe; about $12,500 worth had been exported up to 1902, exclusive of domestic consumption.

Argentina.

Mica deposits have been exploited in Cordova Province in

the north central part of the country. Some sheets have been reported of a size 28x4 inches, but it is mostly small. About $11,000 worth has come to the United States in the years 1898 to 1900, and an additional amount was exported to Europe.

Samples of mica have been imported into the United States from Columbia and Guatemala and Cuba.

Europe.

Small quantities of mica are annually produced in Germany; this may be lepidolite from the Bohemian border, which is mined for lithia, of which Germany has been until recently practically the only producer. Great Britain produced some $8,600 worth of mica in 1897. Russia was from 1891-98 a regular exporter of mica on a small scale. The product was marketed on the Baltic, but no information is at hand as to the location of the producing district. A deposit called the Godfjeld mine has been exploited in Norway, near the southeastern coast, northwest of Kragerö.* The mica here was, however, worthless for many reasons. For many feet from the surface it was partially rotted, and below 100 feet it was likewise rotted or altered to a chloritic material. The mica, which is in a pegmatite dike cutting through mica, hornblende and tourmaline schists and gneiss, is of considerable interest for its defects, although worthless commercially.

Asia.

Burmah.—Mica has been produced and exported from this country, being shipped from Calcutta.

China.—An area of some fifty square miles, about fifty miles from Kiaochao Bay, was discovered by the Germans when they seized that point, and is said to contain "vast untouched deposits" of mica, though much discolored and broken by mineral inclusions.

India.—This is the great mica-producing country of the world. There are two principal regions, namely, that of Behar, in Bengal, and that of Nellore, in Madras, on the east coast; though small amounts have been exported from Bombay on the west coast—probably the production of Coorg, a small province in southwestern India, where mica has also been ex-

*Described by J. F. Wells in Colliery Guardian, Volume 78, page 32.

ploited. The Behar region has three principal districts, those of Hazaribagh, Gaya and Monghyr. In the first, some 250 mines have been opened, of which about sixty or seventy are operated annually. The mines of this district are partly in the Koderma Government Forest Reserve, and the rest are scattered over parts of Gadis-Gawan, Domchanch, Mushnudih-Byria, Dorunda and Satgawan. The principal mines are Dumcho-Gharanchi, Bochagta, Selboya and Kodama. They are from thirty-five to seventy miles from the nearest railway. The climate of this district is an execrable one, parched and desert for six months of the year, and deluged with rain for three months, during which time the mica mines cannot be worked.* The country is made up of a series of parallel ranges of low hills some 400 feet above the surrounding country and 1200 feet above the sea level. These run nearly east and west between Hazaribagh on the south and Gaya on the north, the Monghyr district being situated about seventy-five miles to the northeast of Gaya on the Ganges River. The country rock belongs to the later Archæan formations and consists of gneiss, quartzites and micaceous, hornblendic and tourmaline shists. These rocks are intruded by dikes of mica-bearing pegmatite, and others of fine-grained diorite, both series paralleling the strike and dip of the country rock, as elsewhere. The mica dikes are largely decayed and disintegrated for a distance of 100 feet and upwards, which is no doubt attributable to the excessive rains. Lepidolite is developed on a scale the like of which is seen nowhere else, there being but one white mica mine in Bengal (the Singur mine), and strange to say, in spite of its more frequent occurrence the ruby mica is valued at twice the price of the white mica. In Gaya the principal mines are Singur (white mica), Vita Chatkari, Bind, Govinpore and Korarama. The largest plates reported from the Bengal mines measure about 18x24 inches.

The Madras mica industry is practically new, the mines of Nellore having first become producers for export about 1895. The Nellore district in the coast region north of Madras was the first to be opened, and increased rapidly in importance.

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*This is of course due to the monsoons which blow over the Himalayas for half the year and from the Arabian Gulf for the other half.

Since then two other mica districts have been opened, that of North Arcot to the west of Madras, and that of Nilgris in the southwestern part of the peninsula. The total production of Madras in 1902 amounted to 255 tons, nearly one-quarter of the total production of India. Some of the Madras mica is of immense size, plates five feet long and forty inches wide having been taken from the Itakuri mine of the Nellore district.

Japan.—Mica deposits occur on the Japanese islands, and exports have been made to this country from time to time, but there has been no steady export.

German East Africa.—Mica deposits have been found in the Uluguru Mountains, west of Dar-es-Salaam, just south of Zanzibar, some 100 miles west of the coast. The mica is stated to be of very good quality, and notwithstanding the distance, might possibly show a profit with the excessively low cost of labor existing there.

Philippine Islands.—Mica deposits are reported but have not been exploited.

Australia.—South and West Australia were fairly steady producers of mica on a small scale from about 1890 until 1900, when the exports gradually fell away and finally ceased. Practically all this product was exported to London. The maximum annual production for both provinces was $12,650 in 1894.

New Zealand.—Mica was discovered near Paringa in 1898, but has not been worked.

No doubt numerous other commercial deposits are known to exist, and the above list does not pretend to be complete. It will be observed, however, that only two countries, India and the United States, have been steady producers of granitic mica for any length of time, the former being by far the largest. None of the others seems to offer any great prospects of a steady supply. The immense superiority and ease of working of the Indian deposits taken in conjunction with the low labor cost form a combination which render competition elsewhere all but fruitless.

MAGNESIAN MICAS.

This class of micas has been found in a number of places, as for instance in several localities in New York and New Jersey, and in many foreign countries, in Sweden, Finland, Switzer-

land and Ceylon; but the only known commercial deposits are those of the Laurentian formation in Canada and Northern New York. In this comparative rarity they show a marked contrast to the granitic micas.

The important deposits of this mica are found in a belt beginning in Frontenac county, Ontario, at the northeastern corner of Lake Ontario, and extending northwardly and slightly eastwardly through Addington, Lanark and Carleton counties to Ottawa in Ontario; and thence northwardly in Ottawa county, Quebec, to an unknown limit. In this latter county, most of the best mines are found in the twenty-mile strip lying between the Gatineau and Lievre Rivers. There are also deposits of value to the west of this, running into Pontiac county, and in Ontario west of Carleton in Renfrew county. The formation in the counties named is partly overlain by Cambrian and Silurian rocks, running through Addington county and across the northern portion of Lanark and the southern portion of Carleton counties and also for some miles on both sides of the Ottawa River.

The original source of mica is Ottawa county, Quebec, where it was mined as a secondary product of phosphate mining. When the phosphate mining declined, as a result of the United States tariff and the new phosphate fields of Florida, the mica took its place. As previously explained, mica and apatite are found together in many if not most of the deposits.

The largest mine in Ottawa county is that of Blackburn Bros., near Perkins' Mills, about fifteen miles from Ottawa. It had been exploited on a large scale, with a large force of men, and steam drills, stores, etc., for phosphate before 1888, but in addition to the phosphate an abundance of amber mica was found of excellent quality. There was an open pit 300 feet by 200 feet in area and 130 feet deep; and thence a large lateral drift some 250 feet in length. In developing the mine for mica, the shaft was driven 200 feet below the previous level, but this was subsequently filled in. The mine was provided in 1900 with a seven-horse power hoisting engine and a seven-drill compressor, and eighty-five men were employed.

Another large mine near Perkins Mills is that of Wallingford Bros., which has been worked with fair regularity since 1892, and has reached some 170 feet in depth. The mica is of

fine quality, and drawn from a vein of pyroxene and feldspar about ten feet wide and having a vertical dip. There are two pits side by side, having a total surface area of about 325 by 75 feet, and cross-cuts from the bottom of the smaller pit to another parallel deposit, the outcrop of which appears on the southern side of the shaft.

Other important mines in Ottawa county are those of Fortin and Gravel, west of the Gatineau, a few miles from Ottawa; the Cascades mine on the same side, about fifteen miles north of Ottawa; the Nelly and Blanche mine and the Vavassour mine some nine miles from Ottawa, east of the Gatineau; the St. Antoine mine, formerly the Morin mine, north of Gracefield on the Gatineau (there are a number of unworked deposits of excellent quality in this neighborhood) and the Glen Almond and Allen mines, east of the Lievre River, about fifteen miles above Buckingham.

The mines of Ontario were not developed until some years later, but there is every indication that Ontario will shortly equal or exceed the production of Quebec. The deposits in this province contain mica of unsurpassed quality. In Frontenac county, at the very southern termination of the Ontario mica belt, near Sydenham, is located the Lacey (originally Smith & Lacey) mine, undoubtedly one of the most remarkable mica deposits that have ever been opened, now owned by the General Electric Company. It is now much the largest producer, and has been opened downward for about 160 feet. This mine is located on the east side of Loughboro Lake, across which the mica is transported to Sydenham on the west side. The lode contains mica in massive volume, apparently in a shoot at the junction of a branch vein some twelve to eighteen feet thick, such that the drifts pass much of the time through solid mica. Immense crystals have been taken from this mine. On my visit there I saw several *in situ* from three to four feet in diameter, and a part of a plate some seven feet long was exhibited in the Company's office. I was informed that a crystal was taken from this mine weighing 30,000 to 40,000 pounds, a quantity which in default of exact figures seems highly incredible; notwithstanding which it could be seen that some crystals might well have a volume of a cubic yard or so, which would

weigh about three tons.* The quality varies from the soft, transparent, yellow-brown to the hard, milky variety, and is for the most part of a high grade and quite free from creases.

There are numerous other mica deposits in Frontenac county, some of which have been operated in a desultory way, and doubtless some of these may compare with the Lacey when properly developed. For such development we shall probably have to await, as in the case of the Lacey, the application of American capital on a large scale.

Next to the Sydenham district the most important producing district of Ontario is that of Perth, in North Burgess township, Lanark county, on the north side of Rideau Lake, this belt extending across the lake into South Burgess township, on the south side. Here is located the Hanlan mine, which has been acquired by the General Electric Company, and is being pushed in a similar manner. The mine is situated about nine miles north of the Canadian Pacific Railway, and now comprises a pit about 100 feet deep following the foot wall of a pyroxene dike, and a drift from the base of this shaft along the foot wall in a northeasterly direction. This mine is also noteworthy for large crystals of an excellent quality, though to a less extent than the Lacey mine. The mica is disseminated over a belt about five to eight feet wide.

Numerous other so-called mines are located in this neighborhood, though none of them are now being operated.

South of Ottawa in Carleton county, are numerous deposits of mica, more particularly in March and Huntley townships, which, like most of the others, are not worked.

IV. HISTORICAL.

Mica as a commercial product has its origin in antiquity. How great an antiquity cannot be said, nor is it of especial importance to us to know. In India it has been mined for many centuries, and used for lanterns and other decorative purposes,

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*"One crystal of mica was removed with a length of over nine feet and a breadth of from four to six feet, the quality of which was excellent. Great numbers of smaller sizes occur, and the output generally is of extra large dimensions, the crystals being in great masses, and some of the individuals weighing several tons."—R. W. Ells, Bulletin on Mica, 1904, p. 31.

which in fact have remained as the principal if not the only use for it until the nineteenth century. The *lapis specularis* of Pliny, which was strewn over the arena of the Circus Maximus for decorative effect, is supposed to be a micaceous sand, or the detritus of mica schist. Mica has never, however, been mined in Europe to any important extent, no deposits of value being found there.

India.—In India the mines of the Hazaribagh district of Bengal have been worked for many centuries by the Hindoos. Mica is used on a pretty large scale by native artists, not simply for glazing but for decoration of various kinds, and is a regular staple product. The principal native commercial markets for mica are Patna and Delhi.* Dr. P. Breton, who visited these mines in 1826, found as many as 5,000 people employed in getting out mica, at which time but little was exported to Europe. In 1849 the total output is reported as being over 4000 tons, a figure which hardly deserves credence, when we consider that little of this amount was exported, and particularly as this bears no rational relation to the quantity exported in later years, which, enormous as it is (1858 tons in 1901) is small as compared with this. In 1863 the reported exports of Bengal were about 400 tons; but this is scarcely credible in view of the fact that during later years, 1890 to 1894, when more reliable statistics were at hand, the exports never rose to this figure, although the export industry then was undoubtedly much larger. A. Mervyn Smith estimates that one-half of the total output is at present exported, which makes the above figure for production in 1849 obviously impossible. Government statistics of production, though wide of the exported amounts, vary on the other side of the latter, and though they agree fairly in quantities with the latter, they are on the whole less than, and the values only a small fraction of the exported values. The statistics being then contradictory, it is difficult to fully understand the real extent of the Indian mica industry.

Mining in Madras began to reach considerable production only in the year 1894, since which time a considerable export trade has been developed.

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*The following facts and figures are given on the authority of A. Mervyn Smith, *loc. cit.*

United States.—On this continent mica was mined by one or more of the prehistoric races. The evidence of this is found, first, in the existence of prehistoric pits in the western counties of North Carolina, and second, in the finding of mica specula, consisting of plates of considerable size and very widely distributed over the country, even in the extreme west, in archæological remains—more particularly in the mounds constructed by the Mound-Builders. The commercial exploitation of mica by white men began in the eighteenth century. In 1803 was opened the Ruggles mine, at Grafton, New Hampshire, and this was followed by the opening of a number of other mines in the central and southwestern parts of the same State, and mica mining was for many decades an important industry in New Hampshire. The Ruggles mine alone produced over $8,000,000 worth of mica in the century of its existence, and at one time produced four-fifths of the total requirement of the country.

In 1868, however, mica was discovered in Mitchell and Yancey counties, which lie close to the Tennessee line in Western North Carolina, and cover a portion of the Appalachian plateau, which lies between the parallel chains constituting the Blue Ridge and Smoky Mountains. Between Roan Mountain on the north and Mt. Mitchell on the south—the two highest peaks of this section, and, indeed, of the entire eastern part of the United States—will still be found the best-producing mines in the country. Whether operations for mica really first began here or in Cleveland county, on the southern border of the State, where Hon. Thomas L. Clingman undertook some investigations, is uncertain. It seems that prior to that time the attention of the mountaineers had been called to the possibility of finding something of value in the prehistoric pits of Mitchell county (more particularly the Silvers mine on Crabtree Mountain), by a travelling prospector, who thought that specimens of the rock from this mine looked like silver ore. After some work had been done for silver at this mine, of course without success, it began to be concluded that the only thing of value to be found was mica. This, indeed, is clearly the purpose for which the pits were made, because projecting blocks have been found with the tool-marks around them.

The attention of Mr. Clingman being called to the Silvers mine, he began work there and obtained several hundred

pounds of fine mica. Having been called away from the place, several large blocks of it were left on the ground, one of which was picked up by a passing stock drover and taken to Knoxville, Tennessee, where it was seen by J. G. Heap, of Heap & Clapp, dealers in stoves and tinware, who at once recognized its value, which was in those days many times greater than it is now. The rest of the story of Messrs. Heap & Clapp can best be told in the language of William B. Phillips,* from which the account is principally taken.

"Heap & Clapp first worked the Silvers mine, and by following the old leads obtained large quantities of excellent mica. They cut new trenches, ran an adit in and sank several shafts. They also worked the Buchanan or Clarissa mine, by shaft and adit, and found it equally good. Several other mines were opened and worked, as the Deake and Flat Rock. As local experience was acquired (the *sine qua non* in mica mining, as in every other kind), they extended their operations, so that up to 1882, of the 400,000 pounds obtained, Heap & Clapp must have mined by far the greater part. The average spot value of cut mica then was about $2.00 per pound, some, however, selling as high as $11.00. Even at $2.00 the total value of the mica up to 1882 would be $800,000. As to the profits, no very definite information can now be given."

From the beginning of 1867 or 1868, the mica mining industry rose to a boom in 1869, and rapidly turned to a "fever," which paralleled on a small scale the California gold fever of twenty years previous. People rushed from all parts of the country to the mining districts, and mica prospects were opened in most of the mountain counties of North Carolina. It is a noteworthy fact that the character of the ground changes almost abruptly at the Tennessee boundary, and no mica is found to the west of this line. Mica properties changed hands at fabulous rates, and indeed at $8.00 to $10.00 per pound for cut mica the profits themselves were fabulous, and particularly so for the inhabitants of that part of the country. This lasted for upwards of ten or fifteen years, when a decline began to set in. In the early stages the business was still good, but the price of mica had declined, as it was that time

*Engineering and Mining Journal, April 28, 1888.

(1884) that India mica began to be imported, and the prices of the latter were very much lower than those which had been obtained for the native product. The decline continued and was accelerated by the importation of Canadian mica, which began about 1886, for the latter could also be sold at a much lower price, as it is much more easily mined than the Carolina mica. It seems, moreover, that the excessive cost of large-sized plates had caused the stove makers—then the principal users of mica—to diminish the sizes of their glazing panels, which of course immediately had its effect on the price of the larger sizes, as well as on that of the average price for run of mine. The mica industry remained unprotected against foreign importation until the passage of the McKinley law, in 1890, which placed a duty of 35 per cent. on all imported mica, and thereafter the North Carolina industry revived for a short time, notwithstanding the fact that Indian and Canadian mica continued to be imported in large and ever increasing quantities. It is thought that the increasing demand, due to the rising electrical industry, had at least as much to do with this as the tariff. The Dingley tariff law, which went into effect July 24, 1897, increased the duty on imported mica, making it 20 per cent. *ad valorem* in addition to six cents per pound on trimmed, and twelve on cut mica, the latter having reference to the North Carolina mica.

In the later years some mica mines have been opened in other States, notably in the Black Hills region of South Dakota; but up to the present time these have furnished but a small quota of the total production, though increasing. Mining in New Hampshire has, on the contrary, undergone a slow but steady decline since about 1870, when the North Carolina mines opened. The great Ruggles mine, after supplying mica for nearly a century, was closed on account of litigation about 1898, and I believe it has not since been reopened. At the present time only two or three small mines in New Hampshire are being operated.

Canada.—Canadian mica-mining had its origin as such about 1890, as a sequel to the "phosphate boom" of the eighties, but during the latter period mica had also been mined as a by-product of the output of phosphate rock, since about 1886, when it made its appearance on the market in the United

States. So long as glazing was the only use for mica, the Canadian product, which is unsuited for that purpose, remained valueless, and for several years after it was put on the market, it met with scant notice and appreciation, even for electrical purposes. About 1890-93, however, electrical manufacturers began to realize the fact that there lay at their hand a supply of mica superior in quality for their purposes to the native product, and at a much lower price, and the Canadian mica industry dates its real beginning from that time. The General Electric Company, of Schenectady, N. Y., was among the first to realize this, and has always since continued to be the largest user of Canadian mica. At the same time, owing to new deposits opened in Florida, and the new import duty imposed on phosphate rock, the phosphate industry of Canada petered out, and many of the old dumps were bought up by speculators and ransacked for the mica they contained, which was put on the market in large quantities. The old phosphate mines were reopened and were now worked for mica, so that Canada began to cut an increasingly important figure in the mica market. The principal original source of the mica was Ottawa county, Quebec, and Ontario's quota in the total production was inconsiderable up to about 1895, when its production began to increase and has latterly done so very rapidly owing to the part taken by the General Electric Company, which has since 1901 purchased extensive properties in Frontenac and Lanark counties, Ontario, and more recently also several in Ottawa county as far north as Gracefield, some forty-five miles north of Ottawa.

The entering of the mica-mining field by the General Electric Company is connected with an incident in the industry which deserves mention in this place, and one which had in the end very deleterious results on the profits of the industry. As usually happens in a small, and not infrequently in a large industry, certain operators made an attempt to corner the market for mica, whereby the prices received by producers should be forced down and the prices demanded of consumers forced up. The American Mica Company—the so-called mica trust—was formed in 1900 with a capital of $3,500,000 by a combination of the larger mica dealers, including Eugene Munsell & Company of New York, the American Mica Company of Boston, the W.

H. Sills Mica Company, Chicago, and the Sills-Eddy Company of Canada; and options were secured on most of the other companies so as to control the largest producing mines. It was sought to purchase the bulk of the mica product and hold it in store, whereby a famine should be produced, and the prices should rise owing to increased demand. Apparently, however, the possibilities of this situation had not been fully reckoned on. The General Electric Company, finding its mica supply abbreviated and the future uncertain, determined to secure control of its own supply by purchasing and operating mining properties, thus securing those above mentioned. On the other hand, the abnormal rise in prices produced by the corner, caused a ransacking of old mine dumps, and an opening of new mines, and mica was brought into Ottawa in such quantities that the market was swamped and broken. The natural result followed—a period of prices so low as scarcely to reimburse the producers for the haulage, and many months of depression followed during 1902 and 1903.

In addition to this the producers were themselves, and doubtless still are, under some misapprehension as to the actual state of affairs. The large-sized mica is still being held back, I believe in the hope, if not expectation, that prices will return some day to their former level. Needless to say this expectation will never be realized,—never, at least, until some new use for mica has been discovered, because electrical needs, as aforesaid, are now amply satisfied with small-sized mica. The reasons for the supplanting of continuous sheets by the composite mica-board was not wholly due to the excessive cost of large sheets, but to the fact that the composite product is really a better insulator, as will be explained later.

There can be no doubt, however, that the effect on the industry as a whole, of the action of the General Electric Company must prove a beneficial one, for it is almost the first to have undertaken mica mining on a large scale with plenty of capital, and according to the most approved modern mining methods. These will be explained more fully in the next section.

V. MINING AND MILLING.

Mica as a mining proposition stands in a class by itself, partly because of its different nature, and partly because it has grown up separate and apart from other mining, and progress in the latter has had little influence on the former. Its position is between ore-mining and quarrying. In ore-mining the object is to recover a certain mass of material, and the mechanical condition in which it is taken out is of little or no importance; whereas this condition is of vital importance in the case of mica, whose value depends so much on the perfect mechanical condition of the plates. In quarrying, on the other hand, as for building-stones, slate, etc., the material desired is invariably in massive form, and all that is taken out is utilized. There is no specializing as to direction, it being a simple question of excavation. The mining of mica is somewhat similar to that of non-metallic minerals, such as talc, asbestos, corundum, etc., in some respects, and perhaps has a greater resemblance to that of certain gems than anything else. The mica, instead of being located in a massive plane stratum having a regular strike and dip, follows generally an irregular course, and in the case of the granitic micas, the total mass is so small a proportion of the vein material as to offer strong inducements to what is known as "gophering," or in North Carolina as "hogging," that is to say, excavating from hand to mouth for the purpose of merely getting what is at hand and without reference to any system of development.

Mica, moreover, has until within the past few years, been mined in the most primitive fashion, and to-day the vast bulk of the mining is still so carried on. Almost the only steps in advance beyond prehistoric methods have been the use of metal tools and of explosives; and even the latter improvement is foreign to India mining at the present day.

The prehistoric miners, in order to break up the mica-bearing rock, used, as the evidence appears to show, the well-known fire-breaking method. A large fire was built against the rock, and when the latter was well heated the fire was withdrawn and water thrown against it so as to crack it. Evidences of the use of fire are found in the ancient pits of North Carolina, and no traces of tools are found other than those of stone-hammers,

notwithstanding copper tools from the mines of Lake Superior are known to have had a wide circulation among the Mound-Builders.

In India the task of getting out mica was rendered much easier by the disintegrated nature of the rock, to which, in fact, as well as to the richness of the veins, is to be ascribed the present great development of the industry in that country.

INDIA.

That these prehistoric methods, even to the dispensing with explosives, should still prevail in India is certainly surprising, considering the fact that most of the mines are now worked under European leadership. In Bengal they are worked only during the six dry months of the year, from November to May, this being the season when there is no agricultural work in the fields. The mining of mica is carried on in the crudest way by the farmers of the surrounding country and their families, and alternates with the production of crops, the wet season being unsuited to mining operations, owing to flooding of the mines, as rain descends in heavy torrents. Apparently there is no limit to the quantity of mica contained by the country, and no difficulty in finding mica veins; consequently economy in operating methods is not attempted. Open cuts are made along the outcrops of the dikes where mica is seen in quantity,* and are continued down twenty to thirty feet until the sides have become dangerous. No timbering is used and fatal accidents are of frequent occurrence. The mining tools and methods are of so crude a character that it is not profitable to carry the pits or cuts further down than the depth to which the dike material has been sufficiently disintegrated to make progress easy; and the "hogging" plan, as carried on in North Carolina, is here also the accepted mode of operation. The mining is done by coolies, both men and women, whose wages average three annas (four cents) a day for the men and six pice (two cents) for the women. The former act as miners and the latter take the place of trammers and pumps in a civilized mine, stand-

*The feldspathic gangue is disintegrated by the heavy rains and washed away, leaving the mica-blocks projecting. The spots so found are marked off after the rains for operating during the dry season.

ing or sitting in double line on ladders and in the passages and passing earthen pitchers containing water and baskets containing excavated matter from one to another. The full pitchers and baskets are handed up one line and the empties down the other. In this way it may require as many as seventy women to remove the water from a mine not thirty-five feet in perpendicular depth, though of course the actual line is considerably longer.

The shafts are usually built on an incline and sometimes have a diameter of fifteen to twenty feet, but most are just big enough to allow several pairs of miners to get in and wield their hammers in a cramped position. The tools used consist of a drill, a chisel and a hammer, the drill and chisel being used alternatively and the miners working in pairs, one to hold and one to drive. As no explosives are used it does not pay to carry the operation into the hard rock except where it is very rich, and in this case the ancient fire-breaking method is employed.

Some of the larger mines run to a depth of 100 feet, and a few to even 150 feet in depth. In these cases small vertical ventilating shafts about two feet in diameter are put down to ventilate the inclines, and serve as means for raising the excavated material, for which purpose they are provided with small wooden lifts, called lataps.

In the Hazaribagh district the mines on the Dorunda and Satgawan estates, and those in the Koderma Government Forest Reserve are under Government management, and are leased by the Government at fifty rupees per acre annually, with certain provisions which practically prevent speculation and compel their operation by the lessee. Of the private estate mines, the majority are operated by F. W. Christein & Company, of Tisri, who in 1897 operated 110 mines; the next largest operators were Raj Krishna Sahana (thirty-one mines) and W. R. McDonald (twenty-eight mines) ,both of Koderma.

Work is carried on only in the daytime, from 8 A. M. until dusk. At the end of each day's work the product, which has been brought to the surface, is gathered into bundles, tied with bark-strippings and taken to the manager's bungalow, ready for the trimmers and cutters the next day.

The splitting, trimming and cleaning is done as follows: The

workman sits on the ground before a stout peg, which is driven vertically thereinto, projecting about eighteen inches. He holds a mica block with one side against the peg and opens it with the point of a sickle-shaped knife into slabs about one-eighth of an inch thick. The rough, ragged surface of the plates are then removed with the knife, and they are trimmed around the edges so as to cut away all rough and flawed portions. After trimming, the plates are assorted according to quality and sizes, in four grades of the former and six of the latter, as explained in Section VII. They are then ready for market and are packed in boxes of a hundredweight each and transported on carts to the nearest railway station, varying from thirty to one hundred miles in Bengal. All the product of Bengal goes to Calcutta for export.

The above description relates particularly to the Bengal mining; that of Madras is somewhat more modern owing to its more recent development, but the waste in either case is excessive. The mica mines of Nellore are on government property and are exploited on a lease from the government in a similar manner to those of Bengal.

UNITED STATES.

Mica-mining in New Hampshire and that in North Carolina have from the beginning taken different directions; the method employed in the former State being mostly by open trench, whereas in the latter the shaft-and-tunnel method is that in general use. Until recently hand-drilling only was employed in both districts; but in 1897 Albert J. Hoskins, a large New Hampshire operator, introduced steam drills at his Grafton Center mine, and demonstrated to his own satisfaction that it caused a reduction of 50 per cent. in the cost of mining. Had it not been for the general decline in the industry, there is no doubt that this would have resulted in a general introduction of power-drills. Compressed-air-drills have been introduced in the Alstead district (Cheshire county), and the Davis mine, which is thus operated, turned out the first year 600 tons of scrap and a large amount of sheet, and was reported as being one of the best paying mines of the State.

The great bulk of the mica output of this country is and has

been for many years produced in the State of North Carolina. All the mines in North Carolina, however, strange to say, have stuck to the ancient method of drill-bit and hammer, operated by two men in a gang, one to hold and one to drive. It has been frequqently stated that the North Carolina lode could not be mined with steam drills profitably, because of the amount of good mica which would be spoiled thereby. The theory was that the steam drill would, in drilling the hole, keep right on through quartz and mica alike without discrimination; whereas, by the hand-bit method, one always knows by the yielding of the drill when a mica crystal has been struck. The naive quality of this argument will doubtless seem amusing to those who have used the steam drill in mica mining, as in New Hampshire; but can hardly have much force for anybody who lives north of the Mason and Dixon's line. Although no doubt this contention has a basis of fact, and more care is required with a power-drill than would be with a hand-drill to avoid unnecessary destruction of mica, yet it is undoubtedly for the most part a fiction based on the miner's (particularly the North Carolina miner's) prejudice against anything that is new, and on the fear lest the introduction of power would take away from his earnings, when as a matter of fact there is very good ground for the assertion that it is the only thing which can save the industry in North Carolina. Power drilling has been tried in North Carolina and been pronounced a failure, but there is good reason to suspect the *bona fides* of this trial. When it is understood that the average rate of drilling in North Carolina for two men is about twelve feet a day, whereas a good steam or air drill will do the same work in about two hours, it will be readily seen where the economy comes in, even with labor at $1.00 a day.

There is another theory of those interesting people, the miners, which I believe has never been offered any proof in the domain of fact, and that is that the mica becomes poor in quality, or gives out after a certain depth has been reached. Perhaps this may explain the fact that there are few mines of any considerable depth; but more likely the reason for both of these circumstances is that the rock becomes harder (because less disintegrated) as the mine becomes deeper, and therefore less easy to work with a hand-bit and a sledge hammer. A con-

siderable quantity (just how much would be impossible to say) of the North Carolina product is what we may call the result of off-day work. When the mountaineers have nothing else to do, two of them will get together over a hole in the ground and "hog"* it for a few days, bringing out a half dozen good blocks of mica, perhaps, which they carry to town and sell. One way of working a mine is on the royalty plan, the miner paying the owner of the mine a royalty of ten to twenty per cent. of the product taken out. The miner by this plan has little care what becomes of the mine after he gets through with it, so long as he succeeds in extracting the maximum possible value.

The pegmatite dike or vein containing the mica is usually buried under an overburden of soil, which must be removed; or else an adit is made from the side at a more convenient spot, but requiring the removal of some intervening rock. When the mica lead is reached, it is found frequently to follow the wall of the dike, so that the tunnel may be excavated in the softer country rock. If the lead is followed downward, an accumulation of water makes pumping necessary, but where the mine is on the side of a hill drainage can usually be effected with a siphon or cut-drain. The Ray mine, in Yancey county, has been carried under the Toe River, and several successful mines have been carried to 300 or 400 feet in depth where continuous pumping by power is required, but most of the mines have reached their commercial limit at a less depth, not on account of the failure of mica, but because of the cost of pumping. It is just here that power-mining would undoubtedly pay best, by increasing to so great a degree the quantity of product mined in a given time. In the larger mines the drifts are carried fairly straight, but in others they are quite crooked.

Near by a mine which is in operation with a considerable force, a blacksmith is kept with a portable forge for sharpening drills, and usually the mica-dressing shop is also located here, to which the blocks are taken and where they are first split into

*Hogging a mine means in North Carolina parlance to remove only enough of the rock material to follow the string of mica crystals, and as this passes from one side to another, so the tunnel zig-zags about in a crude fashion, which enables the operators to get out the greatest value with the least amount of work for a few days, but of course renders the task of the next comer more difficult and expensive.

slabs one-eighth to three-sixteenths of an inch thick, and afterward they are thrown into a revolving wire-screen of coarse mesh and washed to remove the dirt. They then pass to the cutter or scriber, according to the way the cutting is done. Rectangular wooden templets are kept on hand in a variety of stock-sizes, and the operator selects the templet which his eye tells him will give the largest possible panel of clear mica from the sheet. The scribers, owing to their experience, are paid high wages, as an inexperienced scriber could spoil many times his cost in mica by faulty cutting. The scriber scratches a line around the edge of the plate with a steel point and passes it on to the cutter, who cuts the plate on the marked lines with a large stationary shears like that used by tinners. In smaller operations the plates are not scribed, but the templet is simply held thereon while the shears cuts around it. The mica as so cut is put up in pound packages of each size, and thence shipped to market by team many miles to the railroad. There is generally a store-house for the cut mica at the mine, and if any quantity of the product is on hand, it is necessary to keep a night watchman with a gun to look after it, for mica to the Carolina mountaineer is just like gold to ordinary people, and while apt to be honest in most ways, he will steal it if he gets a chance.

The manner of handling the mining force is of special importance in mica-mining owing to the power for good or evil they possess over the results. If the miner works by the day he will take no particular pains with his work, and may cost the owner several hundred dollars by careless drilling in a single day. For this reason a vigilant foreman is kept to oversee the drilling and blasting, or else the miner is given sufficient interest in the value of his product to insure good results. Many of the mica deposits are let out on the tribute plan for a royalty of one-sixth to one-eighth of the product, but it is still necessary, where any considerable force is employed, for the owner to have an inspector to insure proper working of the mine and proper returns of mica.

While the North Carolina industry cannot be expected to compete with the imported mica for electrical and some other purposes, still, as first-quality glazing mica, its product is unsurpassed, as indicated by the much higher prices paid. But these prices are much lower than those that were paid twenty years

ago, and it is time for the North Carolina people to realize that these prices have come to stay, and to adapt themselves to that fact. While it cannot be expected that the industry will ever again yield the inordinate profit that it once did, there is no doubt that a great improvement could be made by a scientific application of modern machinery on a fairly large scale, and that what yields a miserable pittance to the mountaineer might be made to yield a very fair degree of profit to the mine owner by a judicious investment of capital in this direction.

The New Hampshire industry is distinguished by the large proportion of scrap and of small sizes, because of which a large, if not the largest portion of the sheet is sent to market in the rough-trimmed condition in which it can be used for electrical purposes. There are undoubtedly many good and workable deposits still existing in New Hampshire, which, however, cannot apparently be worked profitably at present prices. It is understood that litigious quarrels have had a good deal to do with shutting down some of the mines, but it remains true that the industry can show little profit in this State at the present time. The cause is to be sought not in the decline in quality of the mica, or the exhaustion of the mines which once produced so plentifully, but simply in the decline in price. It can readily be understood that mines which would show immense profits when small panels of mica were sold at $8.00 per pound, will not pay to work when the finest cut mica can be obtained at about one-tenth that figure.

CANADA.

In Canada there is a better outlook for modern mining methods than anywhere else in the world at the present time. But even here they have been introduced only on a baker's half-dozen of the best properties. Power-drills were employed back in the eighties in mining the phosphate in the larger mines of Quebec and Ontario, and this method was naturally continued when mica was exploited on the same properties. At the Blackburn mine previously referred to there is a seventy-horse-power hoisting engine, a well-equipped hoisting outfit, and a seven-drill compressor plant. The General Electric properties, in Ontario, however, are the very best examples of modern mica mining, more especially the Lacey mine near Sydenham.

The Lacey mine is located on a rich shoot of mica through which a vertical shaft has been driven about 160 feet deep, which, when I visited the mine, in 1903, served nine levels, and most of the stoping had been done to the south and west of the shaft. The shaft is vertical, about eight feet in diameter, and covered. It is provided with a hoisting-bucket, which as it

Fig. 24. Villeneuve mine, Ottawa Co., Quebec. Muscovite. The boundary between the white pegmatite, and the dark country rock (gneiss) is apparent on the left. The dike is 140 ft. thick. Mined for white mica, feldspar and quartz. Abounds in gems and rare minerals.

reaches the top is carried out at one side and deposits its contents either on a tramcar which delivers it to the dump, or direct to the sorting shop, according to the nature of the material. Ladders are provided around the hoistway for the ascent and descent of persons. The levels did not for the most part extend very far from the shaft, and, as might be inferred from the

nature of the deposit, they formed chambers rather than tunnels, irregular in position, direction and size. Up to the time of its purchase by the present owner, the mine was not worked regularly or systematically, and notwithstanding its incomparable richness, can hardly be said to have made a financial success. The General Electric Company, on acquiring the property, improved the existing workings as far as possible, and plans were made of the different levels, a six-drill compressor plant was installed, and a still further and important new departure has been undertaken in the application of the diamond drill for making test borings, whereby the position and quality of the lode is ascertained. Mica-mining at this mine approaches more nearly the condition of advanced ore-mining than in any other mine in the world. The Hanlan mine, at Perth, Ontario, referred to on a preceding page, is owned by the same company and has been similarly developed, and several others in Ontario and Quebec are in process of development. Power-drills will undoubtedly be employed in all its mines, as it believes that the cheapest and most profitable way to exploit a mica mine is a systematic and orderly way. The ultimate result of this example may be to revolutionize the Canadian industry.

In all the smaller mines mica-mining is still carried on by hand-drilling and blasting, with a horse derrick or whin over the deeper holes to raise the excavated material. The work is carried on fitfully. In summer time most of the mines are idle, this occupation being here, as in India, a sort of spare-time occupation for the *habitants*, carried on when there is no harvest or field-work going on. During the winter, however, the mines become crowded, and on the large properties day- and night-shifts are run. This season is also preferable for the transportation of the mica, it being both easier and less destructive to transport it in sledges or drags on the snow than in carts. As nearly all the mines are a long distance from railways, this is an item of considerable importance. The only mines running a day- and night-shift the year around are those of the General Electric Company.

Although the mica district of Ontario and Quebec is dotted with so-called mica mines, the greater number of them would hardly be recognized as such by one accustomed

to seeing the great or even the little mines of the United States, and the same is equally true of the "mines" of other minerals of Ontario, of which there are a great number and variety. They are little more than prospect holes, pits varying from a few feet to perhaps thirty or forty feet, with no lateral drifts or tunnels of consequence. The district abounds in openings, in fact it seems possible to locate mica deposits with the greatest ease, so numerous are they, but they are little worked, the principal object of the owners of these holes being apparently to sell them to someone else. During the busy season of the year about 500 to 700 men are employed in the Canadian mica mines, a much smaller number than in India, though the total output is by no means so disproportionate. In 1898 a little over two-thirds of the total output was from Quebec, but at the present time the production of Quebec and Ontario is about equal.

The method of preparing mica for market in Canada is about the same as in India. After each blast the mica blocks are separated from adhering rock and those which appear of value are sent to the trimming-shop where they are split to about one-eighth of an inch thick, and the worthless pieces are thrown away. The remainder are rough-cobbed according to size before trimming them, worthless pieces being broken off by the hand, and cracked plates being broken in two. This is done at the mine. The grades are according to the largest rectangular panel if clear mica which can be cut from a plate. Of course it requires some little experience to sort the mica by the eye only. The foreman receives $2.00 to $3.00 a day and the workmen thirty cents to $1.00 according to the value of their services. This work is largely done by boys. Mica while being sorted is placed on sorting tables and thrown into bins from which it is taken and packed into barrels, such barrels holding from 350 to 400 pounds, and they are marked and weighed before leaving the mine. They are then shipped to the cutting factories, most of which are located at Ottawa. On reaching the cutting factory the mica is again overhauled and undergoes several re-sorting, splitting, trimming and cutting operations, each piece passing through a succession of hands. They are first more carefully sorted than at the mine, split to a thinness not exceeding one-sixteenth inch, and after grading according to quality,

Fig. 25. Little Rapids mine, Ottawa Co., Quebec. Amber mica with apatite and pyroxene. Mined for mica and apatite at intervals since 1892.

passed to the cutters, who trim each piece around the edges with a shear in any shape that it will take to free it from flaws. The cutting shear used for this purpose is stationary, similar to that used in North Carolina. In the General Electric factory at Ottawa, where about sixty to eighty girls are employed, all the shears are worked by over-head shafting, and it is only necessary to hold the pieces up to the shears. After being cut, the mica is again graded and sized, and after it is in proper condition it is sent to the fine-splitting tables, which are located on the second floor in the factory mentioned, the remaining work being done on the ground floor. This last process is done without the aid of machinery, and consists merely in splitting the mica sheets by means of a special knife into laminæ of less than a hundredth of an inch in thickness, cleaning out thoroughly all inclusions and dirt, and casting away all imperfect plates. This is done only with the mica used for the purpose of making the compound insulator called micanite, described below. For mica destined for the open market this last process is omitted.

Originally the mica of Canada was treated after the fashion of North Carolina mica, being cut into square panels at the mines; but this process was soon dispensed with, as it was not adapted to electric mica, the necessary forms being of so irregular a character that much mica was wasted, in addition to the extra labor of cutting. The mica was then marketed as knife-trimmed, and this lasted until the beginning of the United States tariff of 1897, which placed an extra specific duty of six cents per pound on "cut or trimmed" mica. This extra duty was at first held to apply to knife-trimmed, but not thumb-trimmed mica, so that for two years no knife-trimmed mica was imported, the whole product reaching the market in *thumb-trimmed* condition, which of course needed the transportation of large quantities of worthless material, but still proved cheaper than the payment of the additional six cents per pound. This was changed again about 1900 by a change of view of the United States Treasury Department, which for some reason decided to place knife-trimmed as well as thumb-trimmed mica under the "unmanufactured" clause of the tariff instead of under the "cut or trimmed" section, as explained in Section VII, whereupon the knife-trimmed mica again began to be im-

ported and has now for the most part replaced the thumb-trimmed mica.

Even the split, cleaned and cut mica for mica-board is now classed as "unmanufactured" mica, so that the only mica coming under the "cut or trimmed" clause is apparently that cut into special shapes or panels.*

Most of the New Hampshire mica goes to Boston for manufacture, some of it, especially the scrap, being shipped to New York for grinding. The bulk of the North Carolina product goes to New York, the remainder to Chicago and to points in Ohio, Michigan and Indiana. The South Dakota product is divided between St. Louis and Chicago.

An important question, for the solution of which there is little or no information at hand, is the question of costs and profits in mining. These vary so widely in the different countries, in different districts, and even in different mines of the same district, that it would be impossible to give any figures which would represent a useful average. The total proportion of mica to material excavated varies from about ten per cent. to one-tenth of one per cent. in North Carolina, according to J. A. Holmes. In India, according to A. Mervyn Smith, it may average thirty-three per cent., while in Canada in some of the richest mines it may run as high as fifty to sixty per cent. The cost of mining per ton is equally variable, averaging perhaps in the neighborhood of $1.00 for many of the North Carolina dikes, and being less in proportion as the quantity of mica per ton is greater; in Canada it is undoubtedly less than this, and in India presumably only a few cents.

Of the total mica mined an indefinitely small proportion is utilizable as sheet—some two to five per cent. as a rule, according to J. A. Holmes, in North Carolina, but undoubtedly considerably in excess of this in some good mica mines, whereas in some mines in New Hampshire it is all reckoned as scrap. Good Canadian mines probably average about ten per cent. in the knife-trimmed form of merchantable product, which is of course all sheet.

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*Just how, why, or by what logical process the "cut or trimmed" clause of the law, which seems explicit enough, has been explained away and whittled down in this fashion is a mystery perhaps worthy the attention of some enterprsing political investigator.

Taking as an example a North Carolina mine averaging one per cent. of crude mica and five per cent. of this as sheet, we would have a total product of one pound of mica per ton, which if it averages a dollar a pound, would roughly approximate the cost of mining. In addition there would be available nineteen pounds of scrap, whose value might run from ten to twenty-five cents.

Manufacture of Mica Board.

In the early state of the electrical industry it was customary to use mica sheets as a whole for the commutators of dynamo machines, this being then almost the only electrical use of commercial importance. It required some years before manufacturers acquired the art of using it for various insulating forms and of combining small sheets of mica into a large and continuous sheet so as to obtain a satisfactory result. Mica board or "micanite," as it was originally termed, was developed by Messrs. C. W. Jefferson and A. H. S. Dyer, in 1892, and they showed that the product when properly made, in addition to being much cheaper than large mica sheets, was also superior to them. It should be remembered that thick plates or slabs of natural mica, such as are used in commutators, are open to several serious objections, the most important of which is the presence of inclusions of foreign matter, which not only destroy in places the continuity of the sheets, but also form, as in the case of rutile and iron oxide specks, paths of short-circuit forming weak points and diminishing the resistance-power of the plate as a whole. Moreover, the plates themselves in their natural state have a polarity developing itself in cleavage planes, that is, lines of weakness along which a crack may be expected; they are apt to be of uneven thickness; and they have little cohesion and are apt to fall apart where not secured together under pressure. In mica board, which is built up of thin separate foliæ, split and cleaned in the manner above mentioned, these defects are eliminated. A surface, as of paper, having the size of a finished sheet of micanite, is coated with shellac, and the thin foliæ are laid thereon so as to cover it in a single layer as nearly as possible. These of course stick to the shellac, and another coat is laid on over them, followed by another layer of mica foliæ so placed as to cover up the

interspaces between the foliæ of the first layer. This process is continued until the sheet is built up to any required thickness, then the whole is subjected to a pressure of 2,000 pounds per square inch, with simultaneous baking by steam heat. The resulting product is *known* to be of uniform quality and free from flaws; but in addition to this, it is of absolutely uniform thickness, and if properly baked will not absorb water, as mica-plates always do wherever there is a slight opening between sheets, giving admission to damp air. It can be easily sawed, cut and drilled, and leaves clean edges. It has no polarity which makes it more easily cut or bent in one direction than in another. Finally, this compound product is cheaper than natural mica, and has therefore superseded it entirely for large-size work, and even for most of that of ordinary size.

In small establishments, the pieces of mica in the manufacture of board are laid on by hand, but in its manufacture on a large scale, this is done by machinery, so that one girl can make a cubic foot in an hour, the work of twenty girls by the hand process.

The manufacture of tubes, cones, rings and various other forms is carried on in a way similar to the above.

Mica Mat Weaving.

This is an art which has been developed principally by the Mica Boiler Covering Company, Ltd., a Canadian-English corporation having its headquarters at Toronto and its factory at Montreal. The mica used for this purpose is scrap mica. Thin leaves of mica are woven together with wire to form mats, whose principal use is as a thermal insulator for covering boilers, and as a protection against fire. The mica is crimped or fluted so as to leave numerous minute air spaces between the sheets. It is not believed that mica itself has a high heat-insulating quality; but taken in a large number of separated sheets, it may easily become so. Conduction of any importance through such a body is impossible, the mica-leaves alternating with air spaces, and convection must necessarily be slow, while radiation is reduced to a minimum by the numerous reflecting surfaces, as well as by the adiathermanous nature of the mica.

This company employs some fifty workmen at its Montreal

factory and manufactures over a ton of scrap mica per day. The process of manufacture is entirely by machinery, most of which has been patented for the purpose. These machines clean, split and crimp the mica and distribute it to other machines, which weave it into mats. They are used largely on the Canadian railways for boiler-lagging, etc., and on several English railways. The boilers of the new British warship "Drake" are lagged with this product.

A similar product is manufactured in Germany.

Mica Splitting Machines.

But little has been done toward the invention of machinery for the manufacture of mica. In this country patents were issued in 1901 to R. W. Heard and R. A. L. Snyder, of Pittsburgh, for mica splitting machines, these patents being owned by the Mica Machine Company of the same place. In the same year a British patent for such a machine was issued to H. C. Mitchell.*

Manufacture of Ground Mica.

In 1870 a patent was issued to Frederick Beck for a process of coating wall-paper with a mixture of ground mica and transparent varnish. When so applied to a surface, the mica has a luster and sparkle which is not only equal to that of metal, but has the vast additional advantage that its luster can never fade or tarnish with age, as all metals must do sooner or later. Moreover, the great cheapness of the mica powder or flour compared with that of metal caused it to supersede the latter entirely as an ingredient of wall-paper decoration, processes for tinting and bronzing it having been invented. At the present time almost all of the cheaper wall-papers are decorated with large quantities of mica paints, while the finer-tinted grades are used even in the higher-priced papers.

It was not until twenty years subsequent to the invention, however, that the Beck patent began to be utilized on any considerable scale. Small quantities of coarsly ground mica were

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*Heard and Snyder's patents Nos. 686,929 and 686,930, issued November 19, 1901; Mitchell's British patent, No. 4969, dated March 8, 1901.

prepared for decorative purposes, such as the production of snow effects on Christmas cards, etc.; but as a staple commodity it has been on the market only since about 1890, and its great development has taken place only within the last few years.

The production of ground mica is not a simple process, nor so easy as might be supposed. In the first place only white mica scrap is utilized, that which is tinged being deficient in luster, and the leaves must be free from rust and specks. The plates must first be beaten up and separated by an opening machine, and divided into comparatively small pieces before they pass to the grinders. Great difficulty was long experienced in grinding, by reason of the soapy or greasy character of the mineral, the plates whereof having a tendency to slide over one another instead of being turned edgewise between the millstones, so that they continued indefinitely without becoming broken up. Both flat and conical millstones have been used with some success, and the grinding is always done with water, but the details of the processes used by the several manufacturers are strongly guarded as a trade secret. After grinding, the ground product requires to be dried, which is a long and rather expensive process as usually carried out.

For the first years of the industry since 1890, a few mills controlled the entire output of mica-flour, the largest of which was the Richmond Mica Company, of Richmond, Virginia. This company attempted in 1897-8 to gain control of the market for mica-flour by buying up the entire scrap-mica output, and thus forcing competitors out of the market for want of raw material. This attempt, however, suffered the usual fate of corners. The price of mica scrap, normally about $7.00 per ton, was run up to $17.00 (according to the "Mineral Industry," or $12,00 according to a native miner), and the finished product was held down; but the artificial market thus created soon collapsed. While it is impossible to suppose that the corner could have lasted very long, the collapse was apparently brought about by the refusal of New Hampshire operators to enter the trust. In the same year (1898) the product of the latter State was run up to 2875 tons, the largest in its history. At the same time the price of flour, which started at the handsome figure of $140 to $200 per ton and was during the period of controlled market from $80 to $90 per ton, broke to about $40 per ton, and the in-

cident closed with the retirement from business of the Richmond company.

Mica is ground to different degrees of fineness, from about ten mesh for spangled effects, lubricants, plastics and fireproofing compounds, up to 160 to 200 mesh for the finer grades of wall-paper.

The mica-flour industry has not been developed outside of the United States. Previous to 1890 considerable quantities were made in Canada, which were presumably utilized for fireproof paints, lubricants and mica-cement insulators. The only market for it was the United States, and when this was taken away by the tariffs of 1892 and 1897 the industry quickly expired.

It must be realized that the development of the scrap-mica industry depends largely on transportation facilities; for the cost of the scrap being but a few dollars per ton at most, a few extra dollars per ton for railroad freights make a prohibitive distinction against such scrap as must pay them, and long-distance teaming is practically out of the question. The New Hampshire mines hold a peculiar advantage in this respect, and those that are still in operation are kept on a paying basis solely by the value of the scrap. In North Carolina, scrap can be sold to advantage as a by-product; whereas in South Dakota, India and other distant localities, the freightage alone on scrap-shipments is prohibitive.

VI. USES.

All the mica industry is to be divided into three principal parts, in accordance with the three principal uses of mica; namely, glazing, electric insulation, and decoration as ground mica. While mica is used for a number of other purposes, it is on these three that the mining industry depends for its existence.

The oldest use of mica, not only by savage, but even by civilized nations, is undoubtedly for decoration.The mica specula found in the graves of America's prehistoric races proves this for the former, as the *lapis specularis* of the Romans does for the latter case. And in India we find it devoted for no one knows how many centuries to many such uses. Lanterns are made

from it for the temples and the bridal processions of the wealthier Hindus; artists use it for their paintings; and inlaid work is made from differently-colored sheets in combination. It forms an ingredient in various ornamental objects, such as toys, flowers, etc. It is also used by the Hindus, mixed with starch, in coarsely-powdered form, as a size for cheap cotton cloths, to give them a sheen.

The art of mica glazing was the next use to develop itself, but appears to be of very recent origin,—apparently imported into Europe from the East through Russia, whence the term "muscovy glass." Its value for stoves and furnaces, where glass would crack, has made it an indispensable adjunct of our civilization, and until fifteen years ago this was the principal use for mica in Europe and America. Practically all the sheet product of North Carolina, and the bulk of the remainder produced in the United States, as well as a large portion of the India mica, is consumed by this industry. The manufacture of mica lamp chimneys has also taken on important proportions in the past few years.

The most important use for mica at the present time, however, is in the electrical industries, as an insulator, and their growth has given an enormous impetus to the production of mica during the past fifteen years, as will be seen from the statistics given in the next section.

As an electrical insulator, mica occupies a peculiar and unique position. There is no substitute for it, nor is there ever likely to be, although, of course, other insulators might be used if mica were unobtainable. It is not only one of the best insulators known from the standpoint of resistance to puncture, infusibility and perfect impregnability to moisture (all qualities of great importance in insulators), but has physical qualities—toughness, elasticity, flexibility, and the extremely thin leaves in which it may be obtained—which render it an ideal insulator in hard every-day service, and these qualities are found combined in no other known substance.

While it is suitable for almost all kinds of electrical work, it finds its chief use in the commutators of dynamos for interposing between the segments thereof. Before mica was universally settled on for this purpose, various substances were tried, but with poor success. Only the softer varieties are suitable

for this purpose, because it is necessary that the insulation-plates should wear as fast as the copper and not project above the surface of the latter, which would cause sparking and irregular running. Generally speaking, white mica, although having a somewhat greater dielectric strength, is unsuitable for this purpose, it being too hard; so that the amber mica of Canada and the soft lepidolite of India are used exclusively. Probably good amber mica is superior to any other kind for dynamo commutators and like purposes, as its present higher price, shown by the statistical charts in the next section, will attest; and it is now being increasingly exported to Europe, which leads to the supposition that there also it has come to replace India mica, which was once used exclusively on the Continent.

Mica is, moreover, being increasingly used as insulation for armature-wires and bars, that is between the conductors of the armature and the iron core; and as for this purpose mica of great flexibility is desired, white mica is also unsuitable, and the amber mica preferred. Armatures whose conductors are insulated by mica are fire-proof, and may be subjected to tests of a very severe character without injury. Those not conversant with electric machinery will little realize how priceless and even vital to our civilization is this one accomplishment, which is rendered possible only by mica.

Great quantities of small-sheet mica,—what would until recently have been termed scrap,—are used for the production of mica-washers, for insulation in lamp-sockets, fuse-blocks and cut-out boxes, and in many other applications in electrical work. For this use any grade of mica is suitable, provided it be free from flaws, specks and rust.

An important use for sheet mica has sprung up very recently and is beginning to attain surprising dimensions, namely, as a sounding-diaphragm. It has been proposed in several patents for use in telephones; but its use in phonographs is the predominating one. The very best leaves for the purpose must be obtained, regardless of cost, as the quality of sounding produced by the instrument depends upon it. India mica has been settled on as the best, and is used almost exclusively. Though the leaves are but $\frac{1}{5000}$ inch in thickness, a single large firm consumes annually thirty tons of mica—equal to two-

thirds of the entire United States production of 1902. Only a small proportion of that bought can be actually used, on account of the perfection required.

The main use for ground mica, as an ingredient of wall-paper pigments, has been referred to in the preceding section. But in addition to this, it is applicable to a great variety of other purposes. It is very largely used in fireproofing and roofing-compositions—usually coarsely ground. The use of ground mica as a substitute for nitro-glycerine, in explosives, is well known, and preceded its present large use as a decorative. Another extensive use for it is in heavy lubricants, this use being founded on the soapy or greasy quality which it possesses in common with graphite and talc. A lustrous hair-powder is, or has been made from it. In the coarser grades it has its use to produce a spangled or frosted effect in decoration and pictures.

Large quantities of coarsely-ground mica are used as aggregating material in combination with a binder, such as shellac, cement, etc., to form plastic compositions, which are used as electric insulators (such as line-insulators) and for applying to metal handles of articles to prevent the transmission of heat.

In India ground mica is applied to a peculiar use, namely, as medicine—said to be efficacious as a remedy for dysentery. The kind used for this purpose is black mica. We might be inclined to smile at the naiveté of the supposition that mica could have any chemical effect on the animal organism; but it is not so improbable as might be supposed, for black mica would be partially decomposed by the gastric juice, and the iron contained therein would undoubtedly prove effective for some disorders. If lepidolite is also used for this purpose (as appears uncertain) the lithia contained therein would be dissolved out in like manner.

Scrap mica has at least one use, aside from that for grinding, which is becoming of increasing importance. I refer to its use as boiler-lagging and for other heat-insulation, which has been described in the preceding section. In principle this must be supposed to rest rather on the numerous polished surfaces presented for reflection of the heat than upon the actual non-conductivity of the material.

(To be concluded.)

Stated Meeting, held Thursday, January 19, 1905.

Tobacco and Sumac. Microscopically vs. Chemically.

By Chester Ahlum.

[The author describes the results of the microscopical method applied to the identification of tobacco and sumac in vegetable materials used extensively by manufacturers of boiler-cleansing compounds.—The Editor.]

In the compounding of boiler chemicals some manufacturers have been making extensive use of vegetable matter, high in tannin, such as sumac and tobacco. The presence of vegetable matter is easily determined in a chemical analysis, but to determine chemically whether tobacco or sumac is one of the ingredients, is difficult and too extended, therefore impracticable in a commercial laboratory where time is a factor.

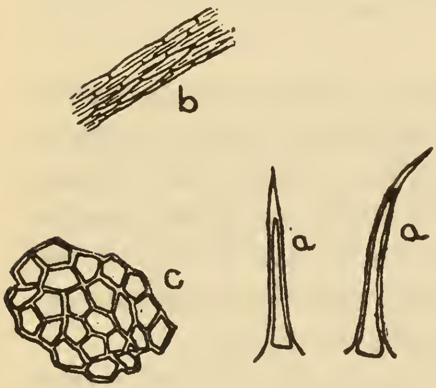
I secured excellent results, by the microscopic method, in the determination of these substances and this method is now being used exclusively in the analytical department of Geo. W. Lord Company. It is much simpler than a chemical analysis and more dependence can be placed upon it.

The process is as follows: If the compound contains soda, or its compounds dissolve in water and bring to a boil, filter off and wash the vegetable matter thoroughly with water, puncture the filter and wash with the least quantity of water possible, into a strong bleaching-powder solution. After the fibre has become bleached wash thoroughly with water and place in a 35 per cent. solution of alcohol. After remaining in this solution about five minutes transfer to 35 per cent. alcoholic Grenacher's Borax Carmine stain, letting it remain until sufficiently stained (about fifteen minutes). Remove, wash with 35 per cent. alcohol and transfer to a weak solution of Iodin Green. In a few minutes remove, wash with absolute alcohol and place in oil of cedar.

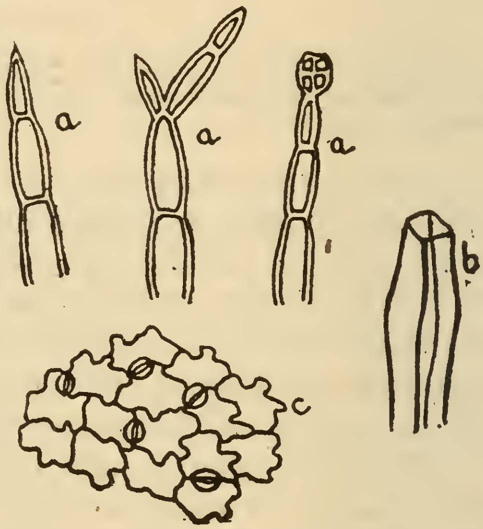
The fiber can be examined in the ordinary way under low power, and if desired may be mounted.

If the fiber is found too small to be handled and in a powdery condition, it may be fixed to the slide by means of collodion fixative. After being bleached, filter, wash thoroughly and fix to the slide by means mentioned above.

Characteristics: Tobacco (Nicotiana Tobacum) is not used in its entirety in the manufacture of compounds, but the rib or stem, presumably because of their small commercial value. Owing to the fact that the stems are almost entirely fibro-vas-



SUMAC
a a—Trichomes or hairs
b—Stem fibre
c—Leaf cells



TOBACCO
a a a—Trichomes or hairs
b—Prismatic cell from stem fibre
c—Leaf cells with stomata

cular and the cells are elongated, the distinction is marked. As in all cases of fibro-vascular bundles the iodin green is taken with great avidity.

The leaf fiber is rarely found in cases of this kind, it being almost entirely removed, but when found it is distinguished by the irregular cells and the abundance of stomata. Hairs are met with occasionally, are multicellular and are of three kinds, single, branched, and those having a cluster of cells at the extremity.

Sumac (Rhus) is used in the form of leaves, and is distinguished by the polyhedral cells and the uni-cellular hairs. The fibro-vascular bundles resemble those of tobacco, but the cells are much smaller. Another marked characteristic is that while

tobacco will take borax carmine very readily, sumac does not, but will take the iodin green.

SUMMARY.

Sumac:	*Tobacco:*
Bleaches slowly.	Bleaches quickly.
Takes the iodin green readily.	Takes the iodin green readily.
Takes borax-carmine with difficulty, or not at all.	Takes borax-carmine readily.
Fibro-vascular bundles composed of elongated cells, smaller than the tobacco.	Fibro-vascular bundles composed of large elongated cells.
Leaf fiber, polyhedral.	Leaf fiber, irregular.
Hairs, unicellular.	Hairs, multicellular, single, branched and lobular.

CONTROLLING INDIVIDUAL WATER SUPPLIES ON IRRIGATED LANDS.

In the irrigated sections of this country the land-owners living along one stream are more or less dependent on each other for their respective supplies of water. One person disposed to appropriate more than his share can readily do so by diverting and holding the water, to the detriment of the farms situated farther down the stream. This is the cause of unending disputes, and all the States in the West have laws designed to overcome it. A new and novel gate arrangement has been recently patented to meet this emergency by L. H. Rhead, a resident of Utah, stationed at the Rio Grande reclamation project, where he represents the United States Government. This gate regulates the flow of water at the heads of distributing canals and laterals, and is especially designed where the scarcity and unsatisfactory distribution of water causes trouble among those concerned. The device consists of an iron gate stem, threaded, and two wheels, also threaded to fit the stem. One of the wheels is for the purpose of raising and lowering the gate, and to the other wheel is attached a chain and padlock, by means of which the second and smaller wheel is locked in any position on the stem, and this constitutes the locking device. This is fixed at a point which will give a land-owner all the water he is entitled to, and will permit him to cut the flow off entirely or partially if desirable, but he is unable to increase it to the point of depriving his neighbors of their share. —*Scientific American.*

ARTIFICIAL ABRASIVES.

The U. S. Geological Survey has just published a monograph on this subject from which we extract the following facts:

Carborundum.—The production of carborundum in 1904 amounted to 7,060,380 pounds, an increase of 2,300,490 pounds as compared with the production of 4,759,890 pounds in 1903. This is the largest production in any year since the beginning of the manufacture of this abrasive and illustrates the increasing demand for it. With the exception of one year, 1902, there has been a continual increase from year to year in the production and use of carborundum, and in that year the decrease was due to a scarcity of supplies used in the manufacture of the carborundum.

Crushed Steel.—The production of crushed steel in 1904 amounted to 790,000 pounds, valued at $55,300, which is the greatest production in any year since this abrasive was first put on the market. As compared with the production of 755,000 pounds in 1903 it is an increase of 35,000 pounds. The average value per pound of crushed steel is 7 cents, the price of the different grades varying from 5½ to 10 cents per pound.

Alundum.—The manufacture of artificial corundum from a bauxite, developed to a commercial basis by the Norton Emery Wheel Company of Worcester, Mass., at its plant at Niagara Falls, N. Y., has met with great success. This abrasive, which is known commercially as alundum, is giving most satisfactory results. The greater part of this material produced by the Norton Emery Wheel Company is used by the company itself in the manufacture of its various emery wheels, stones, &c. There is another artificial corundum that is being used as an abrasive, but it is only obatined in small quantity, as it represents a by-product in the Goldschmidt thermit process. At present none of this corundum is made or put on the market in this country, but at the German factories where the Goldschmidt thermit process is employed it is utilized as an abrasive. In 1904, there were 4,024,000 pounds of alundum manufactured, only a small portion of it being put on the market in the crude form. It was sold at an average price of 7 cents per pound.

PAPER COVERING FOR STEEL.

At th recent meeting of the American Society for Testing Materials, Mr. Louis H. Barker, who is connected with the Pennsylvania Railroad, read a paper on "Protection of Iron and Steel Structures by Means of Paper and Paint," which detailed the results of tests that have been carried on since 1893, using paper instead of paint to protect steel structures. Mr. Baker showed a series of bars, half the length of which had been covered with paper and the other half painted in the usual manner. The paper was put on after the bar had been covered with an adhesive substance, the edges of the covering being lapped. In the samples shown the paper was still intact and unbroken, while the painted portion of the bar showed plainly the need of recovering. The results obtained had been highly favorable to the paper. At the Jersey City station of the Pennsylvania Railroad a very considerable use has been made of the paper covering and with entire satisfaction.

THE FRANKLIN INSTITUTE.

Shaw's Lightning Arrester.

[*Being the Report of the Franklin Institute, through Its Committee on Science and the Arts, on the Invention of Henry M. Shaw. Sub-Committee, Thos. Spencer, Chairman; Wm. McDevitt, C. C. Heyl.*]

(No. 2297.)

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the merits of the Shaw Lightning Arrester, invented by Henry M. Shaw, of New York, reports as follows:

Mr. Shaw has submitted to the Committee for examination U. S. letters patent 724,339, granted to him March 31st, 1903, and also several samples of the commercial form of his apparatus. He has also personally explained to a member of the committee the details of his device, which will be brought out more fully later in the report.

Before describing Mr. Shaw's apparatus in detail, it is thought best to give a short description of the state of the lightning arrester art, and, to a certain extent, its history.

A lightning arrester is a piece of apparatus whose object is to conduct away to the ground the static charges of electricity which may have gathered in an electric conductor, without disturbing the service of the conductor. There are various causes for these charges occurring in electric conductors, but by far the largest number are caused by lightning.

The requisite of a good lightning arrester is that it should perform its work without interfering with the operation of the electric circuit it is supposed to protect; that is, that it should conduct the static charges to the ground without allowing the useful current to follow it.

The simplest apparatus which will theoretically accomplish this consists of two plates of metal so arranged that there is a small interval or air-gap between them, one being connected with the line and the other with the ground. It is easily seen that the air-gap will form sufficient insulation for the low-press-

ure current in the line (usually called dynamic to distinguish it from the static charges), while the static charges will find no difficulty in leaping across the air-gap to the ground.

As static electricity discharges more easily from points, the edges of these plates along the air-gap are usually serrated.

In this form lightning arresters remained for a great many years, their only use being in the protection of telegraph and similar lines, where they were found fully adequate for the purpose.

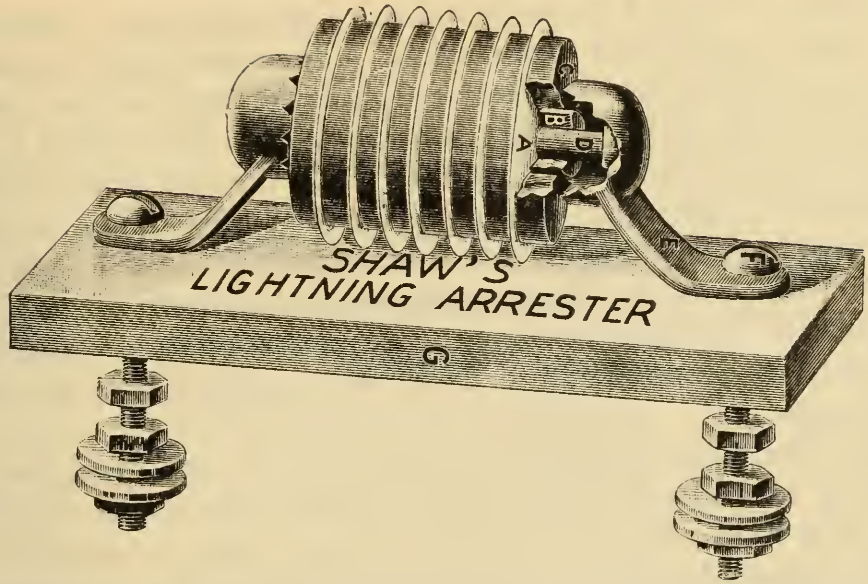
But on the introduction of higher pressure currents, it was found that the dynamic current was liable to follow the static spark across the air-gap, an arc being formed, which would soon destroy the arrester or short-circuit the system. To overcome this difficulty numerous devices were invented, some purely mechanical.

In one an excess of current flowing in the ground circuit caused a magnet to operate a lever, which very much increased the air-gap and so ruptured the arc. As soon as this was done the apparatus returned to its normal condition.

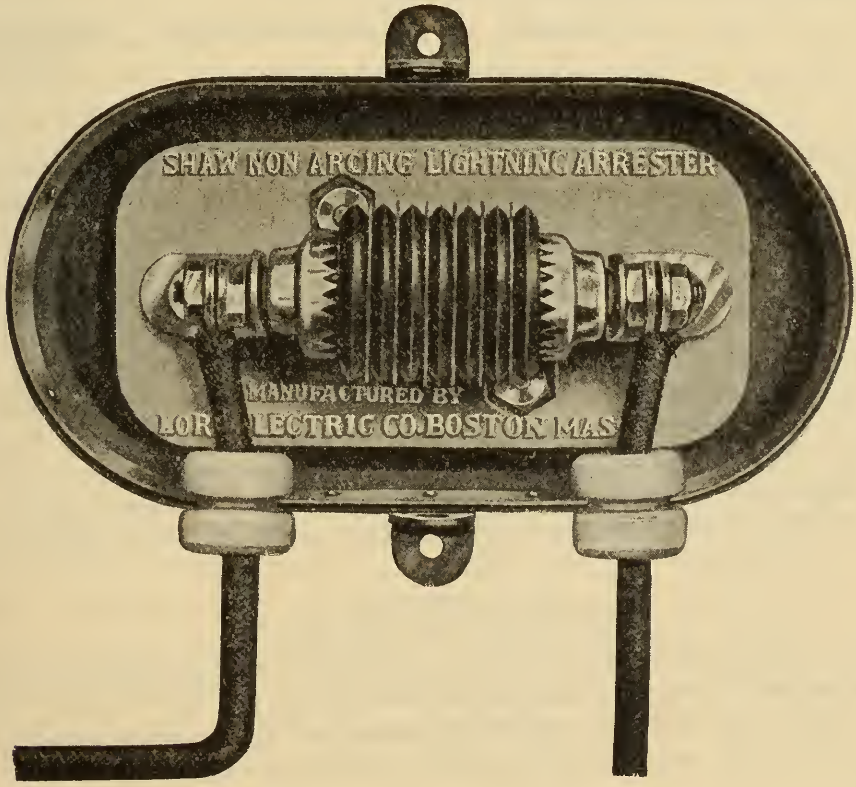
Another depended upon the blowing-out action of a magnet on an arc to rupture it. Still another used the expansion of the air in a closed space caused by the arc itself, to produce the rupture. All these devices were more or less successful. But it was soon discovered that if the air-gap were made up of a series of air-gaps, one after the other, the stepping-stones one might say, being composed of certain metallic alloys usually containing zinc, that a static discharge would easily pass over these steps, but that a dynamic arc would not be formed. Lightning arresters embodying this principle have been constructed in various forms, one of the most common type being a series of short roughened cylinders placed with their axes parallel with a small air-gap between them, the first cylinder being connected to the line and the last to the ground.

Another form is a pile of discs, each disc separated from its neighbor by means of a thin piece of mica. To this class of lightning arresters belongs the apparatus under examination. The drawings and specifications show and describe a piece of apparatus differing slightly in form from the commercial samples submitted by Mr. Shaw, which will be referred to later.

A description of the apparatus is as follows:



Between two brass castings having circular serrated sides, especially prepared high-resistance carbon discs and mica washers are strung alternately on a fibre rod, the whole supported on an insulated base. The brass castings are so constructed that there is a short air-gap between them and the end carbon discs, the serrations on the castings being along this air-gap. The



last point is claimed by the inventor to be important. Although the patent mentions a carbon disc, it does not state that these discs are made of an especially-prepared high-resistance carbon made by introducing foreign substances into the carbon in the course of its manufacture, which is really the case in the sample submitted. This high-resistance feature gives them a great advantage over plain carbon discs when used in a lightning arrester, as their very high resistance makes them act as a sort of insulator and also prevents the formation of an arc, and their conductivity is sufficient to carry without difficulty the static discharges.

The committee therefore conclude that in the main there is nothing very novel in Mr. Shaw's device, but by the introduction of a high-resistance carbon, he has made a valuable improvement and a distinct advance in the lightning arrester art.

As far as the committee can ascertain, the device is original with him, and therefore recommend the award to Henry M. Shaw for his "High Resistance Carbon Lightning-Arrester" of the Edward Longstreth Medal of Merit.

Adopted at the stated meeting of the Committee on Science and the Arts, held January 6, 1905.

Attest: WM. H. WAHL, *Secretary.*

CONCRETE CONSTRUCTION.

Concrete construction has been in use for many years, but is used more extensively now than formerly for foundations, piers and abutments, as well as for bridges. Marked progress was made in concrete construction when the methods of reinforcing concrete with steel were introduced. Concrete arches reinforced with steel ribs or bars, properly designed and constructed, have proved satisfactory for highway as well as railway bridges, and are gradually superseding those of masonry construction.

Reinforced concrete is now used successfully in the construction of floors of bridges and buildings. It has also proven satisfactory for fire-proofing and as a protection to the steel work of bridges over railroad tracks against the corroding influence of the gases from locomotives, and will probably take a permanent place in structural work in the future.—*Iron Age.*

SHIPBUILDING IN 1904-1905.

The Bureau of Navigation of the Department of Commerce and Labor has made public its annual shipbuilding returns for the year ending June 30, 1905. There were 1054 sail and steam vessels of 263,064 gross tons built in the United States and officially numbered during the year.

ELECTRICAL SECTION.

(Stated Meeting, held Thursday, December 3, 1903.)

The Electrolysis of Water.*

By Joseph W. Richards.

The title of this discussion may be a misnomer, because, as is well known, the purest water which can be obtained is practically a non-conductor of electricity, and therefore cannot be electrolysed. In elementary lectures on chemistry, perhaps not more than a quarter century ago, the professor explained, when demonstrating the decomposition of water by electricity, that some sulphuric acid was added to the water so as to make *it* conducting, and then the current flowed and water was decomposed,—but the sulphuric acid had no part or function in that decomposition. The explanation may probably still be regarded as about half true; at least, the final result of passing the current is to give us the constituents of water in the proportion in which they exist in water, and so the sum total of all the actions taking place, simple or as complex as we wish to imagine them, is *the decomposition of water.*

We may conveniently divide our subject into its experimental, its theoretical and its applied phases. The experimental part will deal with the conditions under which water is decomposed, and the facts concerning the electrolytic phenomena; the theoretical part will concern itself with the why and wherefore of these phenomena, and the question of the theoretical connection between the work done in electrolysis and the electric energy consumed; the applied section will treat of the commercial applications of these reactions, the types of apparatus used and the uses of the gases produced.

*Review to date.—J. W. R.

I.

The phenomena of the electrolysis of aqueous solutions which yield oxygen and hydrogen, have been studied for a century. The materials which are dissolved in or mixed with pure water in order that the current may be transmitted are usually sulphuric acid, caustic soda or potash, sulphate of sodium or potassium or carbonate of sodium or potassium. Besides these, many oxygen acids and salts, particularly oxygen salts of the alkaline metals, exercise the desired function, and give the desired gaseous products when worked between proper limits of temperature, concentration of solution and current density; outside of these limits, results different from the normal or obtained.

CONSTANTS OF DECOMPOSITION.

The following constants are those most generally accepted:

Water:	
Molecular weight..................	18
Specific gravity.....................	1
1 liter weighs.......................	1000 grams.
1 coulomb decomposes..............	0.093926 m. grams
1 ampere-hour decomposes..........	0.3351 grams.
Oxygen:	
Atomic weight.......................	16.
Molecular weight, O^2...............	32.
Specific gravity (Air = 1)...........	1.10563
Specific gravity (hydrogen = 1).....	16.
1 liter at 0 deg. C. and 760 m. m. pressure weighs....................	1.4303 grams.
1 gram occupies.....................	699 cub. centimeters.
1 coulomb liberates 0.0829 m.grams =	0.058 cub. centimeters.
1 ampere-hour liberates 0.298 gms. =	207.2 cub. centimeters
Hydrogen:	
Atomic weight.......................	1
Molecular weight....................	2
Specific gravity (Air = 1)...........	0.0696
1 liter at 0 deg. C. and 760 m. m. pressure weighs....................	0.09 grams.
1 gram occupies.....................	11.11 liters.
1 coulomb sets free 0.01036 m. gms =	0.1150 cub. centimeters.
1 ampere-hour sets free 0.0373 gms. =	414.4 cub. centimeters.

Mixed Gases (detonating gas).

Specific gravity (Air = 1)........ =	0.4150
1 liter at 0 deg. C. and 760 m. m. pressure weighs......................	0.563 gram.
1 gram equals......................	1.865 liters.
1 Coulomb sets free 0.0933 m. gms. =	0.1725 cub. centimeters.
1 ampere-hour sets free 0.3353 gms. =	621.6 cub. centimeters.

PHENOMENA DURING ELECTROLYSIS.

It is to be assumed that the electrodes used are such as will be permanent, not being attacked by the electrolyte or the products of its decomposition. Such electrodes are not easy to find, because at the anode the tendency is strongly towards oxidation, at the cathode strongly towards reduction. Even carbon (graphite) used as anode seems to suffer some oxidation, platinum is fairly fixed and gold seems to be practically unattacked. A lead anode is at first superficially oxidized to PbO^2, and having reached the limit of its oxidation remains afterwards unaffected. As cathode, gold is recommended strongly by Mr. Carl Hering as being unaffected; platinum slowly blackens, evidently from the superficial formation of a combination with hydrogen and its subsequent decomposition, leaving spongy platinum; lead cathodes blacken and disintegrate superficially, powdered lead falling to the bottom. The action is evidently analogous to that of platinum, but more active. Iron makes a satisfactory cathode in commercial work.

The electrolytes used in the laboratory are usually dilute sulphuric acid or caustic soda. In the case of dilute acid it is imperative to use as anode a material not attacked by the acid alone, and not forming soluble or insoluble sulphate by the action of the current; the cathode may be any material not attacked by the acid alone, and not occluding,dissolving or combining too actively with hydrogen. In the case of caustic alkali, the anode must be insoluble in caustic alkali alone, and not forming soluble or insoluble oxide or hydrate under the action of the current; the cathode may be any material not attacked by caustic alkali alone, strong or dilute, and not forming easily alloys with sodium or the alkaline metals or occluding or dissolving hydrogen gas. In case the cathode can unite easily with sodium or an alkaline metal, we find that it disintegrates rapidly, evidently because of the successive formation of the

alloy and its subsequent decomposition by the water of the electrolyte.

The electrolyte is warmed by the current passing through it, the heating effect being proportional to its resistance as an electric conductor and to the square of the current passing (Ohm's laws as applied to any conductor). The resistance of the electrolytic cell can be calculated from its dimensions and the known resistivity of the solution used, and thus the energy absorbed for any known current, and converted into heat, can be calculated. Or, the cell can be placed in a calorimeter, and the heating effect of the current measured directly; or, the cell itself may be regarded as a calorimeter, the weights and specific heats of electrolyte, electrodes and thermometer obtained, and from the rate at which its temperature begins to rise immediately on starting the current, the number of calories liberated in it per unit of time can be reckoned up. This latter method, though little used, is probably the simplest, easiest and most accurate of the methods proposed.

Energy disappears in the cell in addition to that which re-appears as heating effect such as is calculated or observed above, and the amount thus disappearing is measured by the difference between the total energy expended by the current and the amount of energy appearing as heat. For every watt of electric energy used, the energy expended may be taken as 0.2385 gram calories. If the electrical energy were all converted into heat, the calorimetric effect which would be measured would agree with the above calculation, *i. e.*, 0.2385 gram calories for every watt-second. But investigation and measurement will show the calorimetric effect to correspond to only a fraction of the energy of the current, generally about one-half. A large part of the energy of the current has therefore disappeared in some other function, and that function is the chemical work of liberating the hydrogen and oxygen from water. We are on safe ground when we say that the electric energy thus disappearing in chemical work is exactly equivalent in amount (measured either in thermal or mechanical units of work) to the chemical work done.

The amount of work necessary to split up nine grams of water into eight grams of oxygen gas and one gram of hydrogen gas is, as nearly as is at present known, represented by

34,500 gram calories. An ampere-hour liberates 0.0373 grams of hydrogen, and therefore does an amount of chemical work represented by $0.0373 \times 34{,}500 = 1287$ gram calories. But, a watt-hour of electric energy represents only $0.2385 \times 60 \times 60 = 859$ gram calories, and therefore we need at least $1287 \div 859 = 1.5$ watt-hours to liberate 0.0373 grams of hydrogen. An ampere-hour of current flow can only represent 1.5 watt-hours of electric energy when it falls in potential 1.5 volts; and therefore we have the necessity that a continuous drop of potential of 1.5 volts must be provided for in order to decompose water, that is, for the chemical work of decomposition.

The work absorbed in the decomposition may also be observed in other ways. If the size of the electrodes be taken, their distance apart, and the conductivity of the acid solution used be known, the heating effect of the current in overcoming the ohmic resistance of the bath can be calculated by the well-known formula $\text{Watts} = RA^2$, and thus the heating effect calculated instead of being directly determined calorimetrically. Agreements will be found to be good, if carefully determined in both ways. The total energy of the current employed being $(V \times A)$ Watts, the difference between $(V \times A)$ and RA^2 is the work done in chemical decomposition. This will be found, if carefully determined, to agree closely with the chemical work done, viz., to amount to 34,500 gram calories per gram of hydrogen liberated, or 2.61 gram calories per cubic centimeter of hydrogen gas, or 1287 gram calories per ampere-hour used.

The rate at which decomposition takes place in any given apparatus depends, of course, on the number of amperes passing through it, but this, in its turn, depends on the voltage maintained across the terminals of the bath, although not in a direct proportion. If a voltage of 1.5 is applied, it will be found that practically no current flows, evidently because that much potential is required to start electrolysis and to provide the energy of decomposition. When a slightly higher voltage is applied current begins to flow, but no visible evolution of gas occurs, with ordinary-sized electrodes, until the solution becomes saturated with hydrogen and oxygen gases. With two to three volts liberal evolution of gases usually results.

When the apparatus is placed under pressure more amperes will pass through for the same applied voltage, or the same

number of amperes can be passed through at a smaller applied voltage. If the latter condition prevails, it will be found that the output of gas per ampere-hour is decreased, and also that the calorimetric heating effect in the cell decreases. The cause of these phenomena is that under pressure considerably more hydrogen and oxygen dissolve in the electrolyte, resulting on the one hand in increasing the amount of re-combination of the hydrogen with dissolved oxygen at the cathode and of oxygen with dissolved hydrogen at the anode, and on the other hand in increasing the conductance of the solution and so diminishing its resistance and the consequent heating effect. Whether the amount of gases evolved per watt-hour is increased or diminished I do not know; this field is ripe for considerable experimentation, since no accurate information on the subject has as yet been published.

The amounts of gases liberated and collected in well-designed apparatus are always less than the theoretical amounts, the loss in oxygen being usually greater than that of hydrogen. Losses of both gases caused by re-combination to form water diminish the amounts of each collected, but diminish them in the same proportion as they are being evolved; that is, for example, if recombination is five per cent., then one-twentieth of each gas is being lost. Temporary loss of hydrogen may occur at the beginning of electrolysis by its absorption by the cathode, which, if of palladium, for instance, could absorb 700 times its volume of hydrogen before becoming saturated; but, such absorption has a limit, and after the cathode has absorbed all the hydrogen it can the action must cease, for good, and thenceforth the normal amount of hydrogen be liberated and no more be lost by cathodic absorption. At the anode, oxygen may similarly be lost at first by superficial oxidation of the anode, but this action usually ceases as soon as a continuous coating of oxide is formed. A lead anode, for instance, in dilute sulphuric acid, is quickly coated with brown per-oxide, PbO_2, with consequent disappearance of oxygen, but the oxidation soon ceases, and no more is thereafter so lost.

Another cause of disappearance of oxygen is the formation of hydrogen peroxide or of persulphuric acid or persulphates in the electrolyte. The amounts to which these may form depends primarily on the strength of acid used, temperature of

the electrolyte and the current density used. Elbs and Schönherr* determined the loss of oxygen in the formation of persulphuric acid, at ordinary temperatures, to be:

Specific gravity of sulphuric acid used	Percentage loss of oxygen using current densities per sq. meter of		
	5 amp.	50 amp.	100 amp.
1.15	....	....	7.0
1.20	....	4.4	20.9
1.25	....	29.3	43.5
1.30	1.8	47.2	51.6
1.35	3.9	60.5	71.3
1.40	23.0	67.7	75.7

In commercial practice the strength of acid used and current density are so adjusted as to fall well within the minimum values of above table, but in laboratory tests these conditions may easily be exceeded, and large loss of energy ensue. It should be observed, however, that when the persulphuric acid in solution reaches the cathode, by circulation or diffusion, it is easily reduced by hydrogen or combines with hydrogen to form ordinary sulphuric acid, thus causing an amount of hydrogen to disappear equivalent to the amount of oxygen absorbed or lost in the formation of the persulphuric acid. Variations in temperature have a very great effect on the possible loss of oxygen by formation of persulphuric acid. Under conditions where 32.2 per cent. of the oxygen was so lost, at 27°C, the raising of the temperature to 60°C. reduced this loss to 0.59 per cent. Running the electrolytic cell warm is one of the best means for reducing this source of loss of oxygen, and of hydrogen also.

Loss of oxygen, very similar in its mechanism to loss by formation of persulphuric acid, may result under special conditions from anodic formation of hydrogen peroxide. The condition favorable for its formation, however, is the use of acid over 60 per cent. strong, and this is rarely or never used in commercial practice. If it were, important losses of oxygen, and also of hydrogen, would occur in the formation and subsequent reduction of the peroxide, in a manner exactly analogous to the formation and reduction of persulphuric acid.

A decreased output of oxygen, measured by volume, occurs

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*Zeitschrift für Eektrochemie *1*, 417,468; *2*, 162,245. (1895).

most frequently from the formation and liberation of ozone, every two volumes of which is formed from three volumes of oxygen gas, so that for every liter of ozone formed the volume of oxygen appears to diminish half a liter. Conditions favoring the formation of ozone are: increased current density, increased concentration of acid up to fifty per cent., low temperature; working with low-current density, weak acid, and warm solution, the amount of ozone formed is very small. For many practical purposes, the formation of ozone does not impair but rather increases the efficiency of the oxygen gas with which it is mixed, which thus gains in intensity of action more than it loses from reduction of volume.

II.

Concerning the *modus operandi* of the evolution of hydrogen and oxygen gases from dilute sulphuric acid or caustic soda solutions, taken as the most important examples, there are many theories. The oldest is, that the acid or salt makes the water conducting, and it (the water) is then decomposed by the current. Another view is that the acid or salt only is decomposed by the current, and that the water present is attacked by the products of this decomposition and thus chemically decomposed. A third view is that the *mixture* of acid and water, or salt and water, conducts the current, and that this *mixture* is the thing which is decomposed, or resolved by the current, into hydrogen, oxygen and acid or salt. These three views may be expressed by the reactions:

$$2\,H^2\,O = 2\,\overset{+}{H^2} + \overset{-}{O^2}$$

$$2\,H^2\,S\,O^4 = 2\,\overset{+}{H^2} + 2\,\overset{-}{S\,O^4}$$

$$2\,S\,O^4 + 2\,H^2\,O = 2\,H^2\,S\,O^4 + \overset{-}{O^2}$$

$$4\,Na\,O\,H = 4\,\overset{+}{Na} + 4\,\overset{-}{O\,H}$$

$$4\,Na + 4\,H^2\,O = 2\,\overset{+}{H^2} + 4\,Na\,O\,H$$

$$4\,O\,H = 2\,H^2\,O + \overset{-}{O^2}$$

$$\begin{cases} 2\ H^{2+2x}\ S\ O^{4+x} = 2\ H^2 + O^2 + 2\ H^{2x}\ S\ O^{2+x} \\ 2\ Na\ O^{1+x}\ H^{1+x} = 2\ H^2 + O^2 + 2\ Na\ O^x\ H^{2x-1} \\ \end{cases}$$

The first theory is untenable, because it is no less logical to speak of the water making sulphuric acid conducting than it is to say that acid makes the water conducting. Pure water is practically a non-conductor, yet a small amount of sulphuric acid mixed with it gives a solution which conducts excellently; pure anhydrous sulphuric acid is practically a non-conductor, yet a small amount of water mixed with it gives a solution which conducts excellently. The only logical and proper conclusion is that the conductivity is a function of the mixing, and that it is the mixture which must be regarded as the conductor of electricity. An analogous case would be the fusibility of silicates of lime. In a blast furnace, pure silica is practically infusible; so is pure lime. Mix them, and the mixture fuses easily in the furnace. No metallurgist says that the lime makes the silica a fusible substance, or that the silica makes the lime a fusible substance; but it is rightly said that the mixture or combination of the two is a fusible substance, and that the fusibility is a property of the mixture only. Likewise to borrow the logical process, the conductivity of aqueous sulphuric acid is a property inherent in and characteristic of the *mixture* and not of either ingredient.

The second theory regards the acid or salt constituent as being the bearer of the electric current, *i. e.*, the conductive constituent of the electrolyte, and as being the constituent primarily decomposed by the current. The first part of this statement is untenable for exactly the same reason as the first theory, which has just been explained at length. If it were allowable or necessary to regard the current as being carried through the electrolyte by the acid or salt constituent alone, then we could acknowledge the force of the corollary, that it alone was primarily decomposed by the current, and that the evolution of hydrogen and oxygen gases was really secondary. But, since the first statement is untenable, the second loses its element of necessity, and must rest upon other grounds of proof or support, if they can be found. The current not being carried by either constituent of the electrolyte alone, but by the electrolyte as a whole, the assumption of the primary and

secondary actions which this second theory requires becomes superfluous and is in fact illogical. Why should the current, after arriving at the electrodes through the medium of the mixed electrolyte, and not through either constituent of it alone, end by decomposing the acid into two constituents which then react upon the water to liberate its constituents? If the current is able to decompose the acid, and the constituents of the acid are able to decompose the water, why not assert at once that the current decomposes the water at the electrodes, and cut out the illogical and unnecessary complication which the theory under discussion involves?

The third theory stands upon the observed fact that only the mixture of acid, or salt, and water conducts; that the *mixture* is, therefore, the conducting body and not either constituent of it; that the current is carried from one electrode to the other as a purely physical operation by the electrolyte or mixture *as a whole*, and not by either of the constituents which united to form it; that, in fact, the constituents of the electrolyte have lost their intrinsic individuality on becoming mixed, having combined with each other or mutually dissolved each other in such manner as to constitute a resultant body or material which contains neither of its ingredients *per se*, but is a compound material which must be considered a unit for the purpose of electric conductivity. This body conducting the current as a whole, from one electrode to the other, the electrochemical action, the chemical decomposition by the electric influence, takes place only at the surface of the electrodes, where the current passes from electrolyte to electrode, and there decomposes the compound body, the electrolyte. In the case of dilute sulphuric acid, the electrolyte contains hydrogen, sulphur and oxygen, in amounts corresponding to a mixture of H^2So^4 and H^2O in some proportion. Calling the electrolyte $H^2SO^4x.H^2O$, we can write this empirically as

$$H^{2+2x}\,S\,O^{4+x}$$

and the electrochemical action is expressable by the formula

$$2H^{2+2x}\,S\,O^{4+x} = 2\,x\,\overset{+}{H^2} + x\,\overset{-}{O^2} + 2\,H^2\,S\,O^4$$

or, perhaps more logically, for the purposes of comparison,

$$H^{2+2x}\,S\,O^{4+x} = 2\,\overset{+}{H^2} + \overset{-}{O^2} + H^{2x}\,S\,O^{2+x}$$

and in caustic soda solution, $NaOH.xH^2O$,

$$4NaO^{1+x}\,H^{1+2x} = 2\,\overset{+}{H^2} + \overset{-}{O^2} + 4\,Na\,O^{2+x}\,H^{2x}$$

On these principles, neither the water nor the acid or salt conduct the current through the bath, but the *mixture* of the two; also, neither the water nor the acid or salt is decomposed, but the *mixture*,—the action of the current being to deprive it (the mixture) of hydrogen and oxygen. These views express more exactly the phenomena, agree more closely with the logic of the situation and the observed facts, and contain no unfounded or unreasonable assumptions.

III.

In Engelhardt's monograph on "Die Elektrolyse des Wassers," he classifies the commercial apparatus used under three heads, according to whether they are used for obtaining oxygen alone, or both oxygen and hydrogen mixed together, or both oxygen and hydrogen separately led off. This classification is, however, a matter of mechanical detail alone, with which we will not concern ourselves.

The real commercial classification is into apparatus with diaphragms and without diaphragms to separate the gaseous products from each other, and further into apparatus with unit couples in multiple and those in series. The multiple or series types have been used according to whether it was desired to work with low or high voltage. Where direct-current electric lighting circuits, of say 110 volts, are available, it is very convenient to have series apparatus adapted to work on those circuits; even when dynamos are installed, it is well to consider that lighting generators of standard voltage are to be found more plentifully on the market, and usually sell at lower prices, than specially-constructed low-voltage machines.

Without further classification we will take up the description of the most successful types of commercial apparatus.

EARLIER FORMS OF APPARATUS.

D'Arsonval, in 1885, was perhaps the first to instal a plant for furnishing oxygen electrically in the laboratory. He used 30

per cent. caustic soda solution as electrolyte, cylindrical sheet-iron electrodes, a current density of two amperes per square decimeter, and enclosed the anode in a woolen bag, to serve as a diaphragm. Only the oxygen was saved. The apparatus used sixty amperes, furnished some 100 to 150 liters of oxygen daily, and was in use several years.

Latchinoff used an asbestos cloth partition, ten per cent. caustic soda solution, iron electrodes, 3.5 amperes per square d.m., and 2.5 volts working tension; or with a five to fifteen per cent. sulphuric acid solution used leads anodes and carbon cathodes. In his first apparatus, the units were all in parallel, but afterwards he used series electrodes, the one side of an electrode acting as an anode and the other as a cathode; a series of forty was used on a normal lighting circuit, with current density of ten amperes per square d.m., and parchment partitions between the electrodes to separate the gases. Latchinoff was also the first to carry out the decomposition under pressure, using a strong iron vessel as electrolyser, and by an ingenious system of floating valves keeping the pressure of the two gases equal in the aparatus. Fig. 1 shows this apparatus, the action of which will be evident from a short inspection.

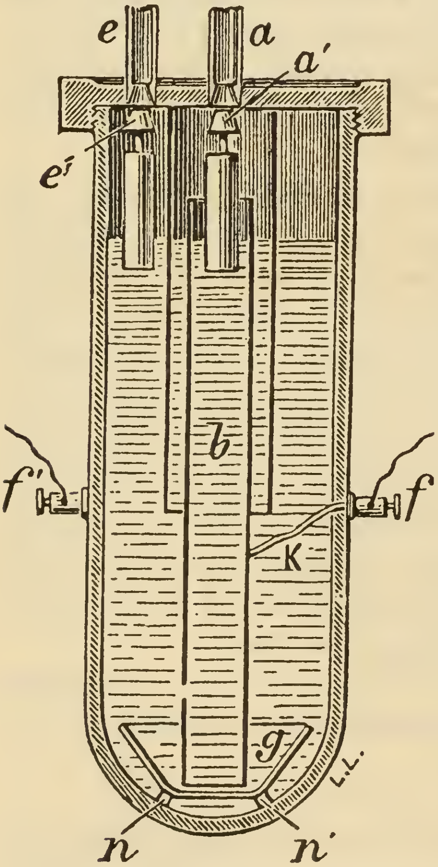


Fig. 1.

Dr. O. Schmidt, in 1899, perfected this series type of apparatus, using bi-polar electrodes, and constructed very practical and workable apparatus in the shape of a filter press, adapted to work directly on 110 volt direct-current lighting circuits. (Fig. 2.)

Each frame in the press contains an iron electrode, which acts as a double-pole (bi-polar) electrode, sheets of asbestos cloth held between the frames acting as partitions, reinforced with rubber on the edges for making tight joints. The electrolyte is ten per cent. solution of potassium carbonate, fill-

ed into the apparatus through the stand-pipe on the right, which communicates with all the compartments through holes in the frames similar to the usual filter-press construction. The gases evolved escape by similar passages into the cylinders on the left end, where they separate from the electrolyte and pass upwards, while the electrolyte, dragged by the gas bubbles, flows downwards back into the apparatus, thus maintaining an efficient circulation. With forty plates, about 2.5 volts is absorbed in each cell, using a current density of about two amperes per square decimeter. The oxygen obtained is 97 per

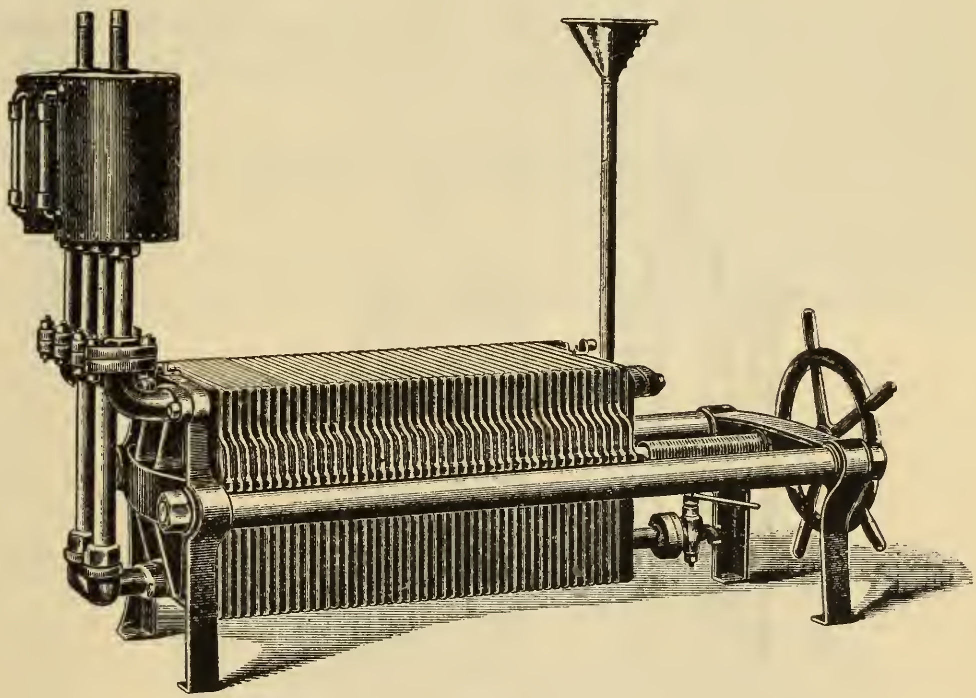


Fig. 2.

cent. pure, which is raised to 99.985, if desired for medical purposes, by passing through a tube filled with platinized asbestos heated to 100 deg. C. Five sizes of aparatus are made, adapted for 15, 30, 60, 100 or 150 amperes, and each may use 25, 40 or 80 frames, for working on 65, 110 or 220 volt circuits. The prices vary from $450 down to $130 per kilowatt of power capacity, according to the size of the machine, and it has been shown that plants in Europe can make good profits when selling compressed oxygen gas at $1 and hydrogen at $0.31 per cubic meter. The Machinen Fabrik Oerlikon in Zurich make

these apparatus, and nearly a score of plants thus equipped are in operation in Europe.

Schoop, in 1900, devised an apparatus with non-conducting and non-porous partitions, which has gone into considerable commercial use. Fig. 3 shows the section of the apparatus, where *a a* are the tubular electrodes of sheet hard-lead, enclosed by glass or clay suspended tubes *c*, which are perforated at their lower ends; the electrode surface is further increased by fine hard-lead or iron wires hung inside the tubular electrodes, the latter being perforated above the level of the electrolyte in order to let the internally-generated gas escape. Each cylinder contains two anodes and two cathodes. When alkaline electrolyte is

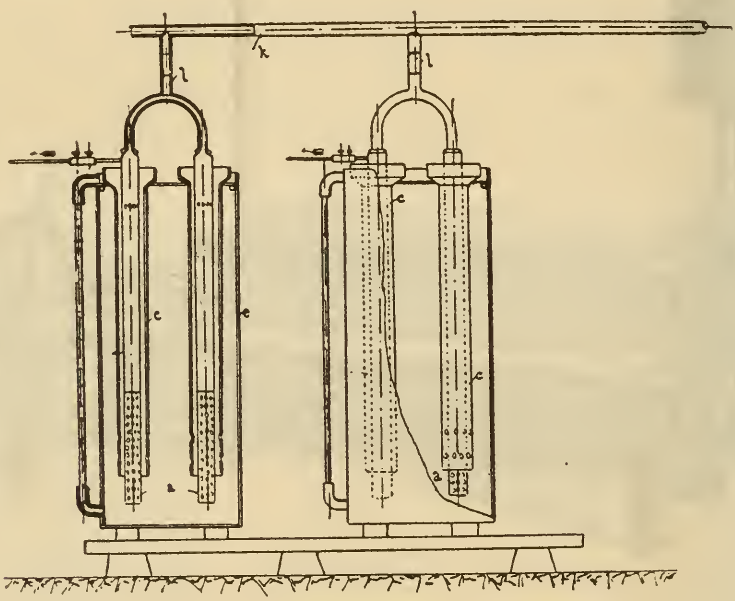


Fig. 3.

used and iron electrodes, the working voltage is 2.25; when sulphuric acid of density 1.235 is used, with hard-lead electrodes, the working voltage is 3.6 to 3.9. The output is given as 68 litres of oxygen and 136 litres of hydrogen per electrical horsepower hour. Fig. 4 shows an experimental plant on this system installed at the Cologne Accumulator works of G. Hagen at Kalk on the Rhine. Only one size of apparatus has so far been made, suitable for 175 amperes and costing $69.25 per unit.

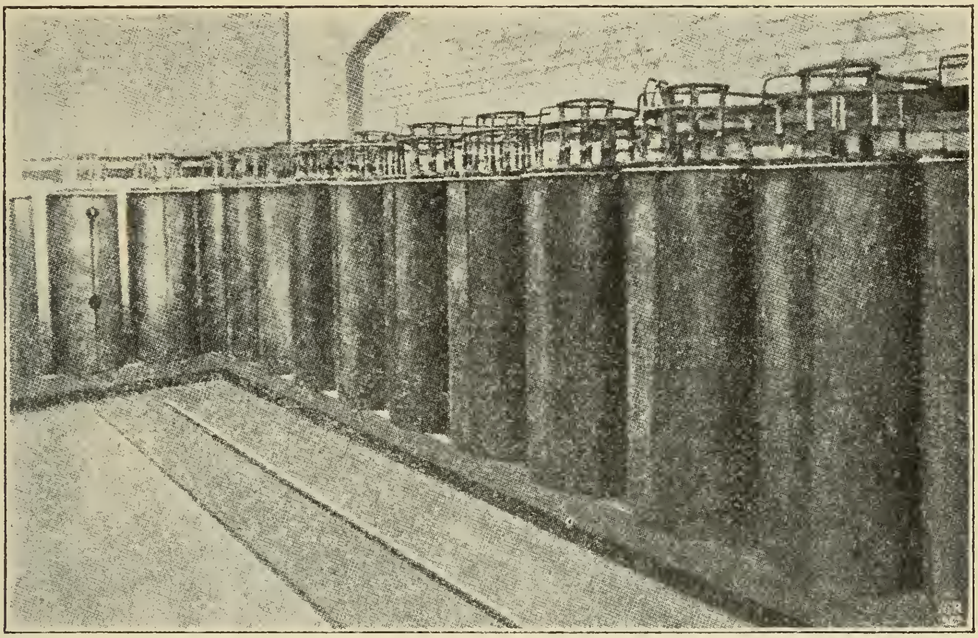


Fig. 4.

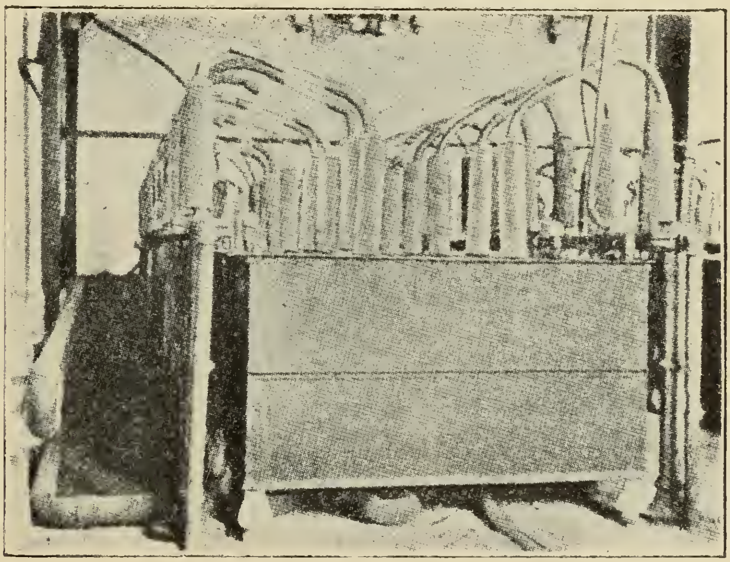


Fig. 6.

Garuti, in 1892, introduced a new electrolytic principle into these apparatus for the decomposition of water. He uses a nearly complete metallic partition between the electrodes, and avoids the evolution of gases on this partition by keeping the working voltage between the electrodes below three volts. It will be easily understood (now that Garuti has thought of utilizing the principle), that the metallic partition can only act as an intermediate or bi-polar electrode by virtue of the current entering and leaving it; but this would make two decompositions between the original electrodes, necessitating an absorption of $2 \times 1.5 = 3$ volts in decomposition. As long as the working voltage is kept below 3, the partition must act merely as a partition, the same as a non-conducting partition. The advantage gained is in the simplicity and economy of making the partitions of sheet metal instead of burnt clay, rubber, glass, etc.

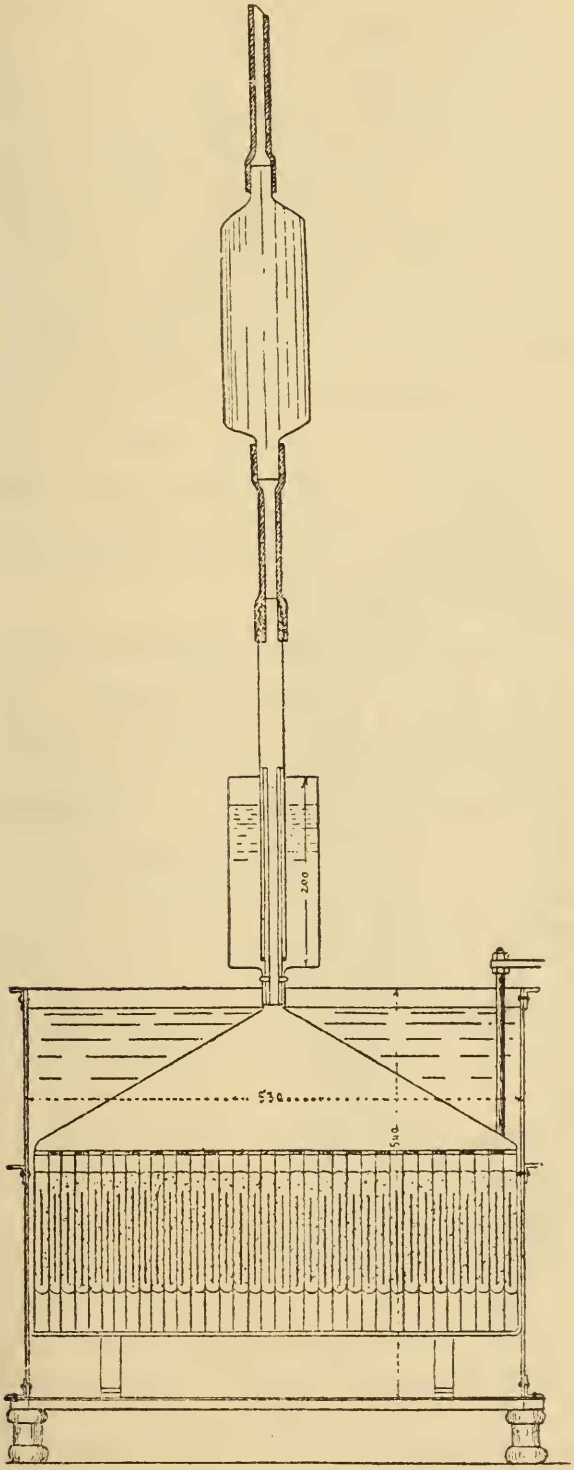


Fig. 5,

Garuti devised many modifications in the de-

tails of his cells, of which Fig 5 may represent the most recent. The original forms made of sheet lead (using dilute sulphuric acid electrolyte) got out of shape too easily, and were replaced by sheet-iron apparatus, using caustic soda solution. The electrodes are only twelve millimeters from each other, and separated by a sheet-iron partition with small perforations in it, the latter allowing free passage of current but being too small to allow any gas bubbles to pass. The alternate compartments are connected with oxygen and hydrogen mains, in which are enlargements for collection of spray and moisture, which runs back into the cell. Current densities of two to three amperes per square d.m. are possible with a working voltage between 2.45 and 3, using caustic soda solution of 21° Baumé. The size cell shown in Fig. 6 is intended to take 400 amperes, and to require one kilowatt of power. A 100-horse-power plant set up at Rome cost $14,000, when transformers and gas compressing plant were added in, $20,000. Nearly a dozen plants are now working on this system in Europe.

Siemens Bros. & Co. and Obach devised the apparatus shown in Fig. 7, the principle being similar to that of Garuti. The cast-iron vessel *a* is surrounded by heat-retaining material, in order that the temperature of the cell may be automatically raised and thus its running resistance lowered. A cylindrical iron anode *f* is separated from the encircling cathode *g* by a cylinder of wire netting *c*, held in place by the porcelain block *k*. The electrolyte is diluted caustic soda; the gases escape above from the spaces n and m. The whole apparatus is set on insulating porcelain feet. The normal type of apparatus is built to take 750 amperes at 3 volts drop of potential, and furnishing eleven cubic meters of oxygen and twenty-two cubic meters of hydrogen per twenty-four hours, using up 162 kilowatt-hours. The cost of this unit is given as $187.50, amounting to $83.25 per kilowatt of current employed.

Schukert & Co. are selling an apparatus which cannot be properly described because it has not been patented, and certain details are kept secret. It is, however, a sort of combination of the ideas of Garuti and Siemens Bros. and Obach. Units taking 200 and 600 amperes have been built, operating at 2.9 volts, and costing only $62.50 each, or $36.00 per kilowatt used. If these figures are correct, it is the cheapest commercial apparatus yet

devised for this purpose; but unfortunately, satisfactory confirmation of these details is lacking.

Laboratory uses for apparatus decomposing water are probably confined to furnishing oxygen and hydrogen, for which any of the above types erected on a small scale, are suitable, or for measuring the electric current. If the volume of gas is found, which is evolved in a given time, the instrument integrates the amperes of current passing; that is, measures the coulombs which have passed. When thus used it has been called a *voltameter,* but the name is a misnomer, and has been abandoned for the much more appropriate term of the oxy-

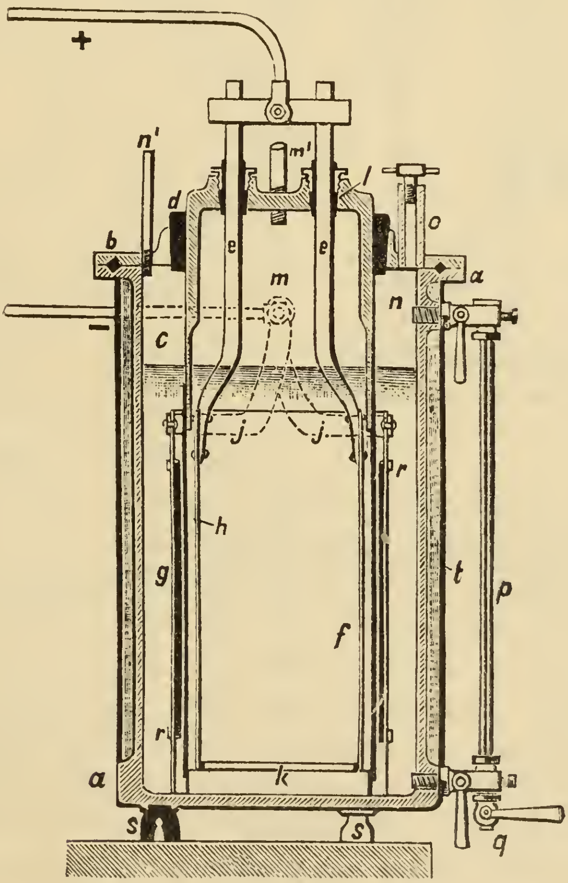
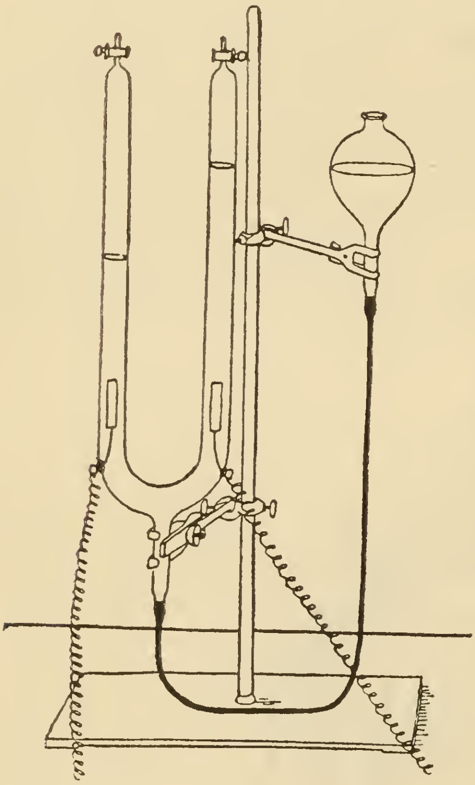


Fig. 7.

hydrogen *coulometer* (coulomb-meter). The laboratory apparatus devised by Hofman is shown in its most recent form in Fig. 8, where the external reservoir enables one to read the volume of either gas at atmospheric pressure. Fig. 9 shows a coulomb-meter for measuring heavier currents, devised by Minet, in which the gases evolved collect in the reser-

voir V and by the pressure which they exert give corresponding indications on the manometer H. The instrument is calibrated by using a constant current passing through a standard ammeter in series, and thus its co-efficient found, the indications being proportional to a constant times the indicated pressure.



The commercial applications of the electrolysis of water are numerous. The mixed gases, or both gases, are useful for obtaining high temperatures, and are used in melting platinum and similar metals, repairing of water-tube boilers, melting together plates of glass, melting out frozen tap-holes of iron blast-furnaces; the Drummond lime light is another application; quite recently blasting cartridges have been devised for dangerously gassy mines, in which water is decomposed by an electric current and the highly compressed mixture ignited afterwards by an electric spark. Hydrogen alone is useful for filling balloons, several European governments having electrolytic plants for filling their military balloons; also for soldering purposes, particularly the autogenous soldering of lead and aluminum. The absence of arsenic makes the electrolytic product particularly desirable, in comparison with the hydrogen made by using zinc and sulphuric acid; also the cost is only about one-quarter as great. Hydrogen has been proposed for lighting railway cars, etc., using very small Welshbach mantles, with resultant advantages in sanitary respects, smaller danger of explosion and smaller piping. Within a distance from the point of production of 180 miles, it has been calculated that the compressed hydrogen is cheaper for this purpose than calcium carbide and acetylene. The uses of oxygen in chemistry, metallurgy, dentistry, medicine, etc., are too well known to need repetition.

In concluding we would refer to a few of the places where further information about the subject treated of in this lecture may be obtained. In the scientific treatment of the subject, we may refer to:

Dr. H. Daneell: Handbuch der Elektrochemie; Specielle Elektrochemie. Lieferung 1. Wilhelm Knapp. Halle. 1903.

S. L. Bigelow: On the passage of a direct current through an electrolytic cell. Journal of Physical Chemistry, December, 1902.

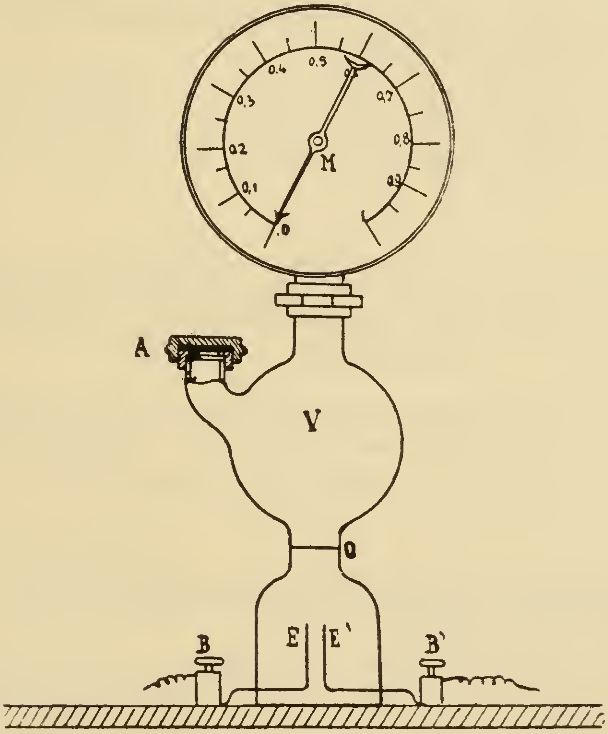


Fig. 9.

C. J. Reed: Gas polarization in lead accumulators. Journal of Physical Chemistry, January, 1901.

J. W. Richards and W. S. Landis: The Electrolysis of Water. Transactions of the American Electrochemical Society, Vol. iii (1903), Vol. iv (1903).

The commercial side of the question has been treated by:

M. N. Schoop: Die Industrielle Elektrolyse des Wassers. 1901.

Engelhardt: The Electrolysis of Water. Translated by J. W. Richards. Chemical Publishing Company, Easton, Pa. 1904.

Various writers: Electrochemical Industry, 1903 and 1904. Particularly December, 1903, page 579.

Book Notices.

The Proceedings of the Chemical and Metallurgical Society of South Africa, with appendix. February, 1897—September, 1899. Vol. II (8vo, pp. xx×928. Johannesburg, Transvaal. Published by the Society. Edinburg: R. W. Hunter. New York: The Engineering and Mining Journal. 1903. (Price, 21s.)

This imposing volume of nearly 1,000 pages, bears excellent testimony to the activity of this society. The subject, which naturally constitutes the theme of many of the published papers, bears more or less directly on the treatment of gold ores, and the extraction of the precious metal, though the volume contains numerous papers treating of theoretical and practical subjects of general professional interest.

The delay in the appearance of this volume is attributed to the disturbing effects of the recent war. Vol. III, which will contain the proceedings of the Society from May, 1902, to June, 1903, is said to be in preparation. W.

Experiments Arranged for Students in General Chemistry. By Edgar F. Smith, Prof. of Chemistry, University of Pennsylvania, and Harry F. Keller, Prof of Chemistry, Central High School, Philadelphia. Fifth Edition, enlarged, with 40 illustrations. Philadelphia: P. Blakiston's Son & Co. 1904. (Price, 60 cents.)

The above entitled edition of this well-known and extensively-used students' guide to experimental chemistry has been enlarged by the addition of a number of new experiments, which add to its usefulness. W.

Western Mill and Smelter Methods of Analysis. Philip H. Argall, B. S., M. A. Denver, Colorado. Industrial Printing and Publishing Co. 1905. Small 8-v , pp. 126. (Price, $1.50.)

This volume describes clearly and consisely the modern chemical methods at present employed in Western mill and smelter operations, and will be found specially useful to the metallurgical chemist wishing to familiarize himself with these methods. W.

Encyclopédie Scientifique des Aide-Mémoires. Librarie Gauthier-Villars, Paris. Small 8-vo. (Price per volume, paper 2 frs, 50c; boards, 3 frs.)

The following-named volumes of this excellent technical series have been issued by the publishers since our last notice. The volumes are sold separately, each being a complete treatise in itself. W.

Nicolardot (P.), Capitaine d'artillerie, Directeur du Laboratorie de Chimie à la Section technique de l'Artillerie. Le Vanadium.

Granderye (L.-M.), Ingénieur Chemiste, Préparateur à l'Université de Nancy. L'Industrié de l'Or.

Stroobant (P.), Atronome à l'Observatorie royal de Belgique, Professeur à l'Université de Bruxelles. Précis d'Astronomie partique.

Martignat (M.), Ingénieur des Arts et Manufactures. Le liège. Ses produits et ses sous-produits.

Jeancard (P.), Ingénieur des Arts et Manufactures, et *Satie* (Conrad), Chef de Laboratorie de la maison Jeancard fils. Abrégé de la Chimie des Parfums.

LeChatelier (H.), Ingénieur en chef des Mines, Professeur à l'Ecole des Mines et au Collège de France. Essais des matériaux hydrauliques.

Granderye (L.-M.), Ingénieur Chimiste, Préparateur à l'Université de Nancy. Détermination des espéces minérales.

Maxwell's Theory and Wireless Telegraphy. Part I. Maxwell's theory and Herzian oscillations. By H. Poincaré. Translated by Frederick K. Vreeland. Part II. The Principles of Wireless Telegraphy. By Fred'k K. Vreeland. 8-vo. pp. xi 255. New York: McGraw Publishing Co. 1904. (Price, $2.00.).

The reader will find this work a most helpful one in arriving at an understanding of the fundamental principles underlying electrical phenomena and their applications in the modern art of wireless telegraphy. W.

Sections.

(Abstracts of Stated Meetings.)

Mechanical and Engineering Section.—*Stated Meeting*, held Thursday, October 5th, 8 P. M.

Present, 102 members and visitors. Mr. Charles Day in the chair.

The evening was devoted to the discussion of the subject of Reinforced Concrete in Construction.

Mr. Emil G. Perrot opened the discussion with remarks devoted specially to the use of this form of construction in buildings, and illustrated his remarks very fully with lantern slides. Mr. Walter Loring Webb followed with a paper descriptive of the use of reinforced concrete in the construction of dams. Mr. Webb's remarks were fully illustrated with lantern views.

Mr. James S. Merritt showed a number of lantern photographs illustrating the use of expanded metal in connection with concrete construction, and explained at some length the abuses to which such construction has frequently been subjected without failure, besides bringing out numerous interesting features in connection with building work.

The following gentlemen likewise participated in the discussion: Messrs. J. O. Ellinger (New York), C. A. Hexamer, H. H. Quimby and the chairman.

The chairman announced that the Executive Committee had appointed Mr. Francis Hand as Secretary *pro tem.* to fill the unexpired term of Mr. D. Eppelsheimer, Jr., resigned. Adjourned.

Kern Dodge, Secretary *pro tem.*

Electrical Section.—A *Stated Meeting* of the section was held on Thursday, October 12th, 8 p. m. President Thomas Spencer in the chair.

The paper of the evening was read by Mr. Lawrence Addicks, of Perth Amboy, N. J., on Electrolytic Copper. The subject was discussed by Messrs. Carl Herring and C. J. Reed. Adjourned.

RICHARD L. BINDER, Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting,* held Thursday, October 19th, 8 P. M.. Present, 19 members. Dr. Wahl in the chair.

The Chairman introduced Prof. Alex. E. Outerbridge, Jr., who read the paper of the evening on Recent Progress in Metallurgy. The paper was discussed by the chairman and the author, and is reserved for publication. The thanks of the meeting were extended to the speaker and the session was adjourned.

GEO. P. SCHOLL, *Secretary.*

Franklin Institute.

(Proceedings of the Stated Meeting held Wednesday, October 18th, 1905.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 18th, 1905.

VICE-PRESIDENT WASHINGTON JONES in the chair.

Present, 48 members and visitors.

Additions to membership since last report, eight.

The Chairman introduced Mr. E. Stütz, of New York, who gave an interesting and instructive communication on American Thermit Practice. The speaker gave a detailed account of the progress that had been made in this country in the introduction of the Goldschmidt process since the presenation of his paper on the subject before the Institute, some eighteen months ago. Mr. Stütz's paper is reserved for publication.

Mr. Louis Edward Levy presented a description with illustrations of his recent invention, termed an Etch-Powdering Machine. In the process of etching metal plates for printing, the design must be so protected that only the ground is etched away and the design left standing in relief. This has hitherto been done by tedious and troublesome hand process, but is effected automatically with this machine. A series of zinc plates, 15 by 18 inches, a number of line and half-tone subjects had been printed with the chrome-albumen process and powdered for the first etch. The first plate of this series was shown in that condition. The second plate presented the same subjects with the first etch completed. second plate presented the same subjects with the first etch completed. The third showed this as provided with a four-way powdering; on the fourth plate the same subjects were shown as left by the second etch after the first four-way powdering, and on the fifth the same subects were presented as ecthed to "routing" depth in a third etch after a second four-way powdering. The work had been done with the powdering machine in the workshop of the Philadelphia *Press.* The speaker named other establishments

in various parts of the country where this machine was being employed. A full description of this invention is reserved for publication.

The thanks of the meeting were voted to the speakers, and the session was adjourned.

WM. H. WAHL, *Secretary.*

Committee on Science and the Arts.

(Abstract of Proceedings of the Stated Meeting held Wednesday, October 4th, 1905.)

DR. EDWARD GOLDSMITH in the chair.

The following reports were adopted:

(No. 2339.) *Schaltung for Induction Coils.* Dr. B. Walter, Hamburg, Germany.

ABSTRACT: The Walter schaltung affords a practical method for reducing the secondary potential of an induction coil, in successive steps, from its maximum potential to its least potential, so that it will satisfactorily operate Roentgen tubes of various resistences when the Wehnelt interrupter is used to operate the induction coil.

The operation of this device with the Wehnelt interrupter in X-ray work has been so satisfactory that although practically the same device has been independently used, the early publication of the same (1900-1901 and 1902) by Dr. Walter, has influenced the Committee in recognizing him as the originator of the device. The report recommends the awarding of the John Scott Legacy Premium and Medal. (*Sub-Committee,* Geo. A. Hoadley, chairman; H. Clyde Snook, Wm. B. Hodge.)

(No. 2359.) *Alternating Current Motor.* M. C. Massie, Washington, D.C.

An advisory report.

(No. 2364.) *Graflex Camera.* Folmer & Schwing Mfg. Co., New York.

ABSTRACT: This invention is the subject of a number of letters patent of the United States (1901-1904) granted to W. F. Folmer. The camera, known as the "Graflex," is an ingenious combination of a well-acting, adjustable, focal-plane shutter, with a mirror set at 45 deg. with the axis of the lens, and between it and the shutter. The shutter cannot be set when the mirror is open and there is a free passage of light from the lens, but when the mirror is closed the shutter can be adjusted to the desired width of opening and set ready for exposure.

The mirror forms a light-tight partition between the shutter and the lens. Immediately over the mirror is a ground-glass focussing screen and an ingeniously constructed hood, which folds compactly under the lid of the box and opens out when the latter is raised, forming a dark passage through which the image thrown by the mirror on the ground-glass focussing screen can be viewed and the focus accordingly adjusted. The image is full-size, and the lighting, the composition and the location or pose of any moving detail can be watched and the exposure made at the very instant desired.

When the button is pressed, the mirror flies up and is cushioned without jar, and when it has raised just far enough to clear the cone of ray from the lens, the shutter is released and its opening passes down in front of the sensitive film. In the 4x5 in. size (which the Committee used) this opening can be varied in width from ⅛ inch to 3½ inches, and the speed at which it passes can be varied in six different degrees, so that the range of equivalent exposure varies from $\frac{1}{10}$ to $\frac{1}{1200}$ of a second.

The report pronounces the design and workmanship of the camera to be excellent in every way. The racking arrangement is very rigid, maintaining the adjustment of the lens under all conditions. The adjustments are accurate and few, considering what they accomplish. The whole arrangement is well thought out and the details well proportioned.

The report concludes by recommending the award to the applicant of the Edward Longstreth Medal of Merit. (*Sub-Committee,* Wm. H. Thorne, Chairman; Samuel Sartain, J. W. Ridpath.)

(No. 2367.) *Drawing Pen.* T. Alteneder & Sons, Philadelphia.

Abstract: This invention is the subject of letters patent of the United Statse, No. 480,541, August 8, 1904. Its object is to enable the user to clean the pen without altering the adjustment of the points.

The invention consists of a fixed blade carrying a pivoted blade opening away from the fixed blade and returning to its position and held there by a spring, the distance of the blades apart being limited by a screw.

The report affirms that the pen is well made and is superior to other pens for the same purpose. The award of the Edward Longstreth Medal of Merit is made to applicant. (*Sub-Committee,* Geo. S. Cullen, chairman; Wm. H. Thorne, W. W. Twining.)

(No. 2366.) *Fuel Saving Devices.* Fuel Saving Company, Utica, N. Y.

(No. 2368.) *Process of Flame Regulation.* Byron E. Eldred, Brookline, Mass.

These two reports were referred back to their respective sub-committees for more detailed information

The following report was heard on first reading and held over for final consideration:

(No. 2322.) *Pressed Steel Products.* The Standard Pressed Steel Co., Philadelphia.

Wm. H. Wahl, *Secretary.*

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Mining and Metallurgical Section.

Stated Meeting, held Thursday October 19th ,1905.

Recent Progress in Metallurgy.

BY A. E. OUTERBRIDGE, JR.,
Professor of Metallurgy, Franklin Institute.

The opening address of the season 1905-6.

Once again it becomes my duty, as well as pleasure, to open the Autumn sessions of the Mining and Metallurgical Section of the Franklin Institute with an address to the members.

I have chosen for my subject a review of recent progress in metallurgy. This covers a wide field, and it will be impossible for me to do more than to touch very briefly upon the results of some of the original researches and their practical applications that have been made and published during the past twelve months.

One year ago it was my privilege to address you upon "The New Theory of Matter," and to present some novel views of the leaders of thought upon the nature of the ultimate particles

of matter out of which worlds are formed. I then said that the new theory was in an embryonic state, and should be accepted with caution, owing to its revolutionary character. Since that time new light has been thrown upon the matter and the views tentatively propounded have been endorsed and corroborated by many prominent men.

The indivisibility of the atom was, until very recently, regarded as an absolute fact; it was indeed a dictum of science; the corner-stone upon which chemistry and metallurgy rested in apparent security. It was believed that there was a score or more of so-called "elements," or primitive bodies, unresolvable into other substances, and built up of extremely minute particles called "atoms," which could not be further divided; these were the units corresponding, as we might say, to the bricks out of which a house is constructed.

Now, a marvelous change has come, due primarily to the discovery of radium and the study of radiations, leading to the growing belief that the atom is not indivisible, but is itself composed of hundreds, in some instances thousands, of smaller particles called "electrons." These electrons are regarded as points of negative electricity repelling each other and moving within circumscribed limits with enormous velocity, even approaching the speed of light.

To quote from a recent writer in *Engineering*, "J. J. Thomson imagines the atom to represent a globe charged with positive electricity, inside of which there are hundreds or thousands of corpuscles of negative electricity, revolving in regular orbits with great velocity. The forces called into play by the electrical inter-action would be very complicated. So far, J. J. Thomson has limited his detailed examination of the model atom to one containing about seventy corpuscles. If the movements of the corpuscles are to be persistent or stable, the corpuscles must revolve in definite orbits, and we thus arrive at an analogy between a complex modern atom and a planetary system. The stability of the atomic unit, regarded as a system, may last for millions of seconds. Finally we may expect it to break up, possibly by rejecting or expelling some of the corpuscles. Then another phase of stability will result. Infinite numbers of such communities would be conceivable, representing an infinite number of elements.* * * The laws which govern electric-

ity in motion indicate that an atom must lose energy by radiation, and must finally run down, as a clock does. In this sense Thomson has spoken of elements which may run for a million years. In radium and in other elements of very complex character, we probably witness this breaking up process and the spontaneous re-arrangement of the atoms which would constitute a transmutation of the elements. The minuteness of the corpuscles must be excessive."*

In my address given a year ago I referred to Lord Kelvin's calculation of the size of the ultimate particles of matter and to his illustration in which he imagined a drop of water magnified to the size of the earth, the molecules would then be of a size intermediate between that of a marble and a cricket ball. The molecule of water contains three atoms, or multiples of three—two atoms of hydrogen and one of oxygen. Prof. Darwin, the President of the British Association, suggested in a recent address on "Evolution," that the three atoms may revolve about one another in a manner analogous to that of a triple star. How much of the space occupied by the molecule is really occupied by the atoms we do not know. Prof. Darwin thinks the atom may bear to the molecule some relation like that of the molecule to the drop of water, and the corpuscles (electrons) may again stand in a similar relation to the atom.

Fascinating as these theoretical studies are, time will not permit us to linger longer in these realms of pure science, but before passing to the more practical phases of my subject I desire to call your attention to a leading article in the same issue of *Engineering* as that from which I have already quoted, entitled, "Steel as An Igneous Rock," of which I will give a brief synopsis.The days in which steel was practically regarded as an iron containing a certain proportion of carbon have gone by. We have learned that the other elements, always present in steel, exert a decided influence on all the properties of the iron; but we are still far from understanding the real nature of the purest steel.

While the inexperienced investigator may too readily imagine that he has struck at the root of the problem, Prof. Arnold

*Engineering, Vol. LXXX, No. 2071, Sep. 8, 1905.

declared in a discourse delivered before the British Association, August 31st, that he had to confess, after research extending over a quarter of a century, that the more he learned about steel the less he knew of its ultimate nature. Homogeneity is the great aim which most metallurgists have in view, but Prof. Arnold thinks that safety is to be found in want of symmetry, not in the visible structure, however, such as the microscope reveals, but in the molecular grouping, about which the microscope does not tell us anything. He regards steel as an igneous rock, more or less crystalline. There is, in his opinion, a certain analogy between granite and steel. The granite is built up of quartz, feldspar and mica; the steel of the constituents of ferrite, pearlite and cementite. In an unsaturated steel containing about 0.5 per cent. of carbon, the microscope allows us to distinguish patches of iron; the saturated steel with 0.9 per cent. of carbon, looks more homogeneously speckled with pearlite; in the supersaturated steel the iron carbide or cementite is seen to form cell-walls, and the cementation proceeds from the outside. Reference is made to several mysterious failures of steel and to micrographic and chemical tests, as well as physical tests of pieces of the metal, none of which offered satisfactory solution of the failures.

The explanation that failures often result from fatigue of the metal is characterised as only "a convenient term coined to mask our ignorance."

The tentative conclusions at which Prof. Arnold has arrived in explanation of certain strange fractures of engine, boiler, and structural steel is, that after the gross crystallization, discernible by the highest microscopical powers, has been completed on cooling, there set in, from a series of centers, molecular movements tending to the production of perfect mineral cleavage. This cleavage cannot easily be detected by the microscope, as steel is absolutely opaque to transmitted light. To avoid the development of cleavage planes the molecular structure of the steel should be asymmetrical. That crystallization proceeds from a series of centers can be demonstrated in many substances, and the decomposition and disintegration will start from the same centers.

I would say, in passing, that while steel is, of course, opaque

to transmitted light of ordinary kind, it is by no means opaque to the passage of X-rays or of radiations from radium.

About two years ago I exhibited in this hall some fine radiographs showing the permeability of steel and cast-iron to the X-rays and to the radium radiations. It will be remembered that in the case of cast-iron there was a decided difference in permeability or transparency to the rays between a specimen of ordinary gray cast-iron and a companion piece of the same iron of the same thickness that had been permanently expanded to a remarkable degree by repeated heating and cooling, whereby the particles of iron were permanently separated farther from each other, and the metal was rendered comparatively porous.

Reference was made by Prof. Arnold to an accident caused by failure of an end-plate of an old boiler, which had cracked completely across, in which the tests subsequently made of the metal could not account for the accident.

It has always seemed to me that there is one inherent defect in the prevailing practice of testing such metal, by cutting coupons from the plates after failure, in that they are tested at the ordinary temperature of the atmosphere, but the failure occurs usually while the metal is hot. It is, therefore, interesting to note that some elaborate tests of the "Elastic Properties of Steel at High Temperatures" have been recorded in a paper read before the Royal Society by Prof. Bertram Hopkinson and F. Rogers, of the University of Cambridge, printed in *Engineering* Sept. 8, 1905. In these experiments the elastic properties of steel and iron have been investigated at temperatures ranging up to 800 deg. C. (1452 deg. F.) It was found that "as the temperature rises the stress-strain relations undergo a remarkable change, which may be best expressed by saying that what is variously called the 'time-effect,' or *elastische nachwirkung*, or 'creeping' increases greatly with the temperature. Steel at high temperatures behaves like india-rubber or glass; if it is stressed for a time, and the stress removed, it does not at once recover; but after the immediate elastic recovery there is a slow contraction perceptible for many minutes. Such creeping can be detected at ordinary temperature, but at red heat attains a different order of magnitude,

becoming (in its total amount) a substantial fraction of the whole deformation."

Tests pieces 4 inches long and 0.2 inches in diameter between shoulders, having enlarged threaded ends screwed into two steel bars 10 inches long $1\frac{1}{8}$ inches diameter, were used, the whole being enclosed in an electric resistance furnace wound with three coils of nickel wire. The currents in these coils could be separately controlled, and in this way the temperature along the test piece could be maintained very approximately uniform. The temperatures were measured with three thermo-couples, placed one at each end and one at the middle of the test piece. Changes in length could be measured correctly to $\frac{1}{50000}$ inch by means of an extensometer. The furnace was supported separately, and the test-bar, with the attached extensometer was hung free within it. Tension up to $1\frac{1}{2}$ tons per square inch could be very rapidly applied or removed; the interior of the furnace was closed from the atmosphere by means of mercury locks, and the test piece was kept surrounded by an atmosphere of nitrogen, so as to avoid oxidation. Diagrams accompanying the paper show the results of a series of tests carried out on a steel bar at 750 deg. C. This bar was at no time heated much beyond that temperature. It was loaded with 85 pounds (about $1\frac{1}{4}$ tons per square inch) for one minute, then unloaded for two minutes, and so on, and the curve shows the resulting changes in length in terms of the time. Even at this low stress the metal flows fairly rapidly, and the overstraining has a considerable hardening effect, as is shown by the diminishing amount of permanent set produced by successive loadings. This hardening disappeared with rest, that is, if the bar were left unstressed at 750 deg. C. for a couple of hours after having been hardened by successive loadings, it was restored to its original soft state.

In respect to all the features mentioned the properties of the material differ only quantitatively from those of a cold bar but for one remarkable difference. This difference lies in the behavior of the bar after the removal of the load. The cold bar does not contract appreciably; there is the instantaneous elastic contraction, then it stops. The hot bar, on the other hand, goes on shortening for two minutes or more after the load is off, and the total shortening amounts to about one-third of the

instantaneous contraction, or one-quarter of the total contraction. This phenomenon is analogous to residual change in glass and other di-electrics, the stress corresponding to the electric force, and the strain to the electric displacement. The magnitude of this effect in steel may best be gauged by comparing it with other cases of the same kind, *i. e.*, with the slow recovery of the glass fibre after twisting; if such a fibre be twisted through a considerable angle for several hours, it will recover all but one-fiftieth of the twist within two or three seconds of the removal of the stress. The remaining slow "creep," amounting to one-fiftieth of the whole deformation, corresponds to the slow return of the steel.

In India-rubber, under certain circumstances, 10 per cent. of the stress and the strain disappears in time after the removal of the stress. But in steel at 600 deg. C. the proportion is about 15 per cent.

One effect of such a time-lag will be to cause dissipation of energy if the material be subjected to alternating stress, for it will lead to a difference of phase between the stress, and the strain; and the amount of the dissipation will depend upon the period of the oscillations.

The authors state that another effect of the "creeping" is to make the determination of Young's modulus a matter of some uncertainty, but it would take too much time to consider this phase of the subject here. For further particulars I refer to the original article, which I found exceedingly interesting.

A few months before the publication of these tests of the elastic properties of steel at high temperatures, Mr. R. A. Hadfield, President of the Iron and Steel Institute, read before that association his remarkable paper on the effect upon the mechanical and other properties of iron and its alloys produced by liquid air temperatures. This is a highly interesting and valuable contribution, giving the results of numerous costly and carefully-conducted original investigations. The author stated that as many iron alloys had shown anomalous results in their physical behavior at ordinary temperatures, it became desirable to ascertain the exact effect of very low temperatures upon such bodies, and accordingly he carried out a series of tests on standard iron and on iron alloyed with other elements. In the course of the inquiry no less than five hundred specimens were

examined. The bars experimented on were finished to .18 inch in diameter and were 2 inches long in the parallel part and 3.20 inches over all. The size of the specimens, therefore, did not vary greatly from that of the tests made by Prof. Hopkinson on the elastic properties of steel at high temperatures. The two investigations had no relation with each other, but it seems appropriate that they should follow one another as a corollary.

The first specimen examined by Mr. Hadfield was of Swedish charcoal iron, approaching pure iron in its composition. The analysis gave Fe. 99.82, C. 0.045.% Si. 0.07% S. 0.005% P. 0.004% Mn. trace.

This iron, after careful annealing, gave twenty tons per square inch tenacity, and 20 per cent. elongation at normal temperature; after cooling in liquid air the tenacity rose to thirty-eight tons, with substantially no elongation. Another specimen, after being quenched at 950 deg. C. and and again at 600 deg. C. in water, showed similar results in liquid air. Two other specimens in the unannealed condition, and one after special heat treatment, showed similar properties. Specimens immersed in liquid air, and allowed to return to the normal temperature before testing, had almost exactly the same tenacity and elongation as before cooling, thus showing that the brittleness was entirely a function of temperature. In addition to tests made on specimens of steel with various amounts of carbon, alloys of iron and chromium, tungsten, silicon, aluminum and copper were tested. Mr. Hadfield's conclusions are as follows:

"Practically at this low temperature (—182 deg. Cent.) pure iron has its tenacity more than doubled; its well-known ductility falls very low; its magnetic properties remain almost the same as at higher temperatures.

This represents the general behavior of all the alloys, excepting those containing nickel, which are less affected, as regards loss of ductility, whilst an iron alloy containing 5 per cent. of manganese and 25 per cent. of nickel has its extraordinary ductility, about 60 per cent., still further increased, and the tenacity also largely increased. Manganese steel has its ductility lowered; but its non-magnetic properties remain apparently unaffected. The whole of the results combine to offer a most

interesting field for observation of the physical properties of iron, both at ordinary and at liquid air temperatures."

Related more or less closely to these investigations we may properly refer briefly to the great advance that has been made in knowledge of the influence of heat treatment on the physical properties of steel, and of the practical use that is being made of these observations. We now know that the proper heat treatment of steel rails before, during and after rolling is of vital importance in the production of good rails. Good material may be spoiled by bad treatment at a critical moment of the rolling. The microscope has found a field of great usefulness in enabling the chemist to determine whether a failure is due to faulty heat treatment or to other causes.

Passing now to the consideration of recent advances of a practical nature in metallurgy, it seems to me that one of the most interesting developments within the year has been shown in the paper of Mr. Jas. A. Gayley on the application of dry air in blast furnace practice. So much has been written upon this subject since the original paper appeared in print that it would be superfluous for me to do more than allude to it here. While it was by no means a new observation that the amount of moisture in the atmosphere exerted a decided influence on the product of blast furnaces, no one had apparently anticipated the gain in economy which Mr. Gayley showed by his method of freeing the air of its moisture before passing into the furnace. So remarkable are these results that various theories have been advanced to account for them of more or less abstruse nature. It remains still to be seen whether the method will be found sufficiently advantageous and economical to warrant its universal adoption. In these days of scientific progress in the production of pig-iron in enormous furnaces, new methods meet with prompt encouragement from furnace proprietors and it is to be hoped that Mr. Gayley's ingenious plan will prove thoroughly successful.*

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*The September record of two Isabella furnaces at Pittsburgh, one of which is operated on the Gayley dry-air blast and the other on ordinary blast, is interesting, says *The Iron Age*. No. 1 furnace, with the Gayley refrigerating plant, made a ton of iron with 1939 pounds of coke, while No. 3, using ordinary blast, required 2339 pounds, a lowering of the coke consumption in favor of the Gayley dry-air blast of 400 pounds per ton of iron.

GOLDSCHMIDT'S SYSTEM OF ALUMINO-THERMICS.

During the year we have had a fine demonstration in this hall of various practical applications of Dr. Goldschmidt's ingenious and simple process in the production and utilization of very high temperatures by means of mixtures of aluminum with a metallic oxide, such as oxide of iron, and we also have the report of the sub-committee on Science and Arts on the invention, which unanimously recommended the award of the Elliott Cresson gold medal, the highest in the gift of the Institute, to Dr. Hans Goldschmidt, of Essen, Germany, for his discoveries in "Alumino-Thermics." This award was confirmed by the Institute.

In addition to the welding operations exhibited here with marked success, the process is adapted to and is practically applied to the production of rare metals free from carbon, which are finding immediate use in the metallurgical arts, thus: Chromium 99% pure, is now made by this process for steel alloys, produced either in the crucible or in the open hearth; also Molybdenum 99% pure, and free from iron. Manganese of equal purity is similarly made. Ferro-Titanium containing as much as 25% of the latter metal, and various other alloys, such as Manganese-Copper, Manganese-Tin, Manganese-Zinc, &c., are furnished commercially, made by this process. It is interesting to remember that pioneer work in this field was conducted years ago by two distinguished members of the Franklin Institute, Drs. Wahl and Greene, who were the first to employ metallic aluminum as a reducing agent for the production of the difficultly reducible metals, and who placed carbonless manganese and chromium on the market in commercial quantities a number of years before the Goldschmidt process was announced.

Calcium can now be obtained commercially. The usual impurities are Silicon 0.2 to 0.5%, aluminum 0.2 to 0.3% together with traces of iron. The specific gravity of pure calcium is 1.52. Calcium has been found to be sufficiently tenacious to be

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No. 1 furnace made 413 tons of iron per day, as compared with 362 tons for No. 3, a gain of 51 tons per day. It should also be noted that No. 1 was running on Bessemer pig and No. 3 on basic, the former carrying 0.5 per cent of silicon more, so that iron made in No. 1 should realy have used more fuel.

drawn into wire as fine as 0.5 millimeter in diameter, and these wires have a specific electric conductivity of about 16 per cent of silver.

MAGNETIC NON-IRON ALLOYS.

Prof. J. H. Fleming and R. A. Hadfield in a recent Royal Society paper, give the latest results of their work of investigation of the magnetic qualities of some alloys not containing iron. The alloy experimented with was composed of manganese, 22.42%; copper, 60.49%; aluminum, 11.65%; carbon, 1.5%; silicon, 0.37%; iron, 0.21%. About 2 or 3 per cent. of slag was intermingled, mostly consisting of manganese and silicon oxides, with slight traces of metals other than the above mentioned. The conclusions of the paper are as follows:

The above alloy exhibits magnetic properties which are identical with those of a feebly ferro-magnetic material.

The magnetization curve is of the same general form as that of a ferro-magnetic metal, such as cast-iron, and indicates that with a sufficient force a state of magnetic saturation would most probably be attained.

The alloy exhibits the phenomenon of magnetic histeresis. It requires work to reverse the magnetization of the material and to carry it through a magnetic cycle.

The material has a maximum permeability of 28 to 30, which is not greatly inferior to that of the values reached for cobalt or a low grade of cast-iron for small magnetic forces, and occupies a position intermediate between the permeability of the ferro-magnetic and the merely paramagnetic bodies, such as liquid oxygen and ferric chloride.

The material exhibits, therefore, the phenomenon of magnetic retentivity and coercivity. It is not merely magnetic, but can be permanently magnetized.

A further conclusion is that the magnetic properties of this alloy must be based on a certain similarity of molecular structure with the familiar ferro-magnetic metals. The hypothesis which best fits the facts of ferro-magnetism is that materials such as iron, nickel and cobalt, are composed of molecular groups, which are permanently magnetic, and that the process of producing or changing the evident magnetization of a mass of these metals consists in arranging or disturbing the positions

of these molecular magnets. Since, then, we have in this alloy an instance of fairly strong ferro-magnetism produced by an admixture of metals possessing in themselves separately no such property, it follows that ferro-magnetism *per se* is not a property of the chemical atom, but of certain molecular groupings. The importance of this fact cannot be easily overstated. It shows us that in spite of the fact that ferro-magnetism has been hitherto regarded as the peculiar characteristic of certain chemical elements—iron, nickel and cobalt—it may, in fact, depend essentially on molecular grouping composed of a comparatively large number of molecules, and, hence, it may be possible to construct alloys which are as magnetic, or even more magnetic, than iron itself.

Commenting on the paper, the London *Electrician* says that the discovery of the secret of the molecular grouping referred to would be of immense importance, as it will lay bare the whole mystery of magnetism, and might make possible the manufacture of a material even more magnetic than iron itself.*

BY-PRODUCTS.

The utilization of so-called "waste products" is daily becoming more and more important, and in some industries the recovery of by-products, which were formerly thrown away, proves actually more profitable to-day than did the original operation in former times. Among the inventions aiming to recover waste products most deserving of notice here is "Clamer's Method of Eliminating Metals from Mixtures of Metals." This process was investigated by the Committee of Science and Arts and the Elliott Cresson medal was awarded to Mr. G. H. Clamer for his invention, which has been patented and pushed into successful operation on a large scale in this city and elsewhere.

The report of the sub-committee states that the invention is a new method of utilizing brass scrap, and producing therefrom a merchantable bronze, or a material which can be used in the manufacture of merchantable bronze. If it is attempted to remelt scrap brass for use again the iron which unavoidably

*Electrical World.

contaminates it, together with the lead and tin of the solder and oxide of zinc produced during the melting, make a remelted metal which is practically worthless. The Clamer process eliminates the oxidizable mixtures in an ingenious way by so regulating the ingredients of a charge of scrap and waste products for the furnace, based upon analysis of the scrap, that there shall be sufficient quantities of oxides of copper, lead or tin to oxidize a certain quantity of zinc and iron. Not only are the impurities removed by these reactions, but the purifying materials on performing their function, and by reason of their reaction, are themselves reduced to the metallic state and contribute copper, lead and tin to the bath. For every 65 parts of zinc or 56 parts of iron oxidized, there would be furnished 127 parts of copper or 207 parts of lead, or 118 parts of tin, or aliquot proportions of these, according to the proportions of oxides of copper, lead or tin used. This fact is economically of great importance, because, the oxides of copper, lead and tin are found commercially in large quantities as waste products, called copper scale, and lead and tin dross, or skimmings, and are purchasable at a comparatively low price. By utilizing these waste products as active agents to eliminate impurities from another waste product, the deleterious materials (zinc, iron, oxygen) are all eliminated by mutual reaction, and only the useful combination, copper, tin and lead, remains.

The practical operations are conducted on the hearth of a reverboratory furnace, lined with magnesite brick, and are simply and easily managed.

FERRO-SILICON IN THE FOUNDRY.

Among the comparatively new metallurgical products for which I think an increased use will be found, is an exceedingly rich ferro-silicon alloy, containing from 50 to 80 per cent. of silicon.

Ferro-silicon containing from 12 to 20 per cent. of silicon has been a commercial product for a long time, but the new very rich silicon alloy possesses distinctively valuable properties which I have discovered in the course of some extended investigations not heretofore published.

One of the difficult problems of foundry practice where mis-

cellaneous castings are made is to economically obtain from one melting in a cupola different grades of iron suitable for different classes of castings requiring perhaps very different qualities of metal. Thus, the articles may range from castings of many tons weight, usually of thick section, requiring strong iron of close grained texture, often having high chilling properties, to small objects of a pound or so in weight, frequently of thin sections, which require to be machined, and therefore must be of softer metal having little or no tendency to chill.

As silicon is practically the *governor* that determines the degree of hardness of cast-iron, the value of a simple process that will enable the intelligent founder to control the proportion of silicon in any individual ladle of molten iron drawn from a cupola is apparent, especially in foundries where miscellaneous castings, ranging in size from small pulleys weighing a few pounds, with rims one-quarter inch thick, up to anvil blocks, bed plates for various machines, hydraulic cylinders and the like, sometimes weighing many tons and of varying thickness, up to twelve inches or more, as is the daily practice in the foundry with which I have been connected for many years. The silicon in such castings ranges usually from $2\frac{1}{2}$ per cent. to less than 1 per cent., and the customary method of operation is to group all the small work so that it will be cast at the beginning of the heat, followed by a medium grade of iron suitable for miscellaneous castings of medium weight and thickness, this again followed by large and heavy work requiring strong iron of close-grained texture, low in silicon, and having high chilling properties.

By arranging the work so as to have a certain number of castings to serve as "buffers," *i. e.*, to take iron that is intermediate between the different grades charged in the furnace, this method has proved very satisfactory, and now it can, I think, be supplemented by *altering at will the silicon in any individual ladle*, to a nicety that is truly surprising.

In this way it is possible and practicable to use a lower grade of iron in the general mixture than could otherwise be done. At present the operation is confined to treating ladles of iron for the lightest class of work, requiring the softest grade of iron, so as to permit of machining at high rates of speed; but, when the price of ferro-silicon, containing 50 per cent. and up-

wards of silicon, shall fall, as I have little doubt it will, to a more reasonable figure, the use of it in the way I have here indicated will become general. I am led to make this assertion from experience based on my original investigations with ferro-manganese (80 per cent. manganese) in car-wheel iron in the year 1886. The cost of ferro-manganese was then more per ton than the present price of ferro-silicon (50 per cent silicon). To-day it is less than half that price, and the use of ferro-manganese for certain purposes, especially in chilled cast-iron car wheels, in the way I described in my lecture on "Cast-Iron," printed in *The Journal of the Franklin Institute*, March, 1888, and in practically the same proportions, has long since become well established. It has been stated in print by a recent writer that when the Pennsylvania Railroad authorities adopted the "thermal test" for car wheels, the wheels of nearly all the makers failed to stand this test, until a small quantity of ferro-manganese was added in the ladle just before pouring. This gave the metal additional elasticity that enabled the wheel to resist the severe strains caused by heating the rim suddenly in the thermal test.

As the result of a large number of experiments made with test bars of foundry iron treated with small quantities of ferro-silicon (50 per cent. Si.), say one-quarter to one per cent., I have found an average gain in strength of about 15 per cent, and a somewhat larger average gain in ductility, or bending quality, accompanied by a marked increase in softness of the metal.

I have here a number of test specimens of the treated and untreated iron; those which show most plainly the softening effect are the wedge-shaped castings six inches long, four inches wide, one-quarter inch thick, tapering to a feather-edge, cast of medium grade foundry iron and split down the middle to show the grain. In some of these the untreated sample is white all through, in others it is white at the thinnest portion only, but in all the specimens cast from the same ladles after treatment with from one-quarter to one per cent. of ferro-silicon, the casting are gray throughout and soft enough to drill or file.

The silicon in the untreated samples ranges from 1.7 to 2.25 per cent, and in the treated specimens from 2 to 2.75 per cent. I find that the addition of even so little as one pound of this alloy, in a powdered form, in a ladle containing

200 pounds of foundry iron produces a remarkable effect, not only as a softener, but what is more surprising and equally valuable, it is invariably accompanied by an increase in strength and resilience, or ductility, of the metal, although we have added actually a little less than 0.25 per cent. of silicon to the iron. By adding four times this amount of the alloy to a very hard iron mixture of iron in a ladle which ran quite white when cast in thin sections, and was, therefore, entirely unsuitable for small castings requiring to be machined, I have found that I can produce a soft gray metal of good strength and ductility with low shrinkage, suitable for casting pulleys and other light work.

I am, of course, aware that it is not new to use brands of silvery iron, known as "softeners," containing five, ten, or perhaps even fifteen per cent. of silicon, in the manufacture of iron castings, but so far as my experience goes in commercial practice, covering thirty years, the addition has been made in the cupola itself, which results in either what may be considered as a fixed product, or, if varied during the heat, in a product which is indeterminate, so as not to be predictable at at a given moment of tapping.

I believe, therefore, that it is a new discovery to note the immediate diffusibility of the high-grade ferro-silicon when added to a relatively small quantity of melted cupola iron which has been withdrawn from the source of heat supply, and its capacity, when thus diffused, to produce definitely controllable results in the physical characteristics which are essential in different grades of castings.

The cost of the small addition of high-grade ferro-silicon in the ladle, even at the present price of the powdered alloy (about four cents per pound), is trifling, and is far more than counterbalanced by the fact that lower grades of pig-iron may be used in the furnace, besides the practical value of being thus able to absolutely control the product and to vary the character of the metal in regard to softness, or machining quality, at the same time increasing the strength and ductitily of individual ladles of iron drawn from one common source.

ELECTRO-METALLURGY.

Wonderful progress is being made wherever cheap power from water-falls is obtainable in all branches of electro-metallurgy. In Europe they are actually making steel at various places in electric furnaces in a commercial way. A commission of experts was appointed by the Canadian Government to visit Europe and study these methods, and it is now reported by Vice Consul General Gorman, of Montreal, that the Dominion Government has appropriated $15,000 for making experiments with the electric process of smelting ores and manufacturing steel at Sault Ste. Marie, and the Consolidated Lake Superior Co. will furnish a building and dynamo capable of supplying 400 electric horse power for four months free of charge. All kinds of ores will be experimented with, and important results are expected to be obtained.

Great possibilities for Canada underlie the inauguration of a cheaper process for manufacturing pig iron and steel than is now in use. Ontario is dotted with ore bodies, the development of which is at present prevented by lack of cheap fuel. There is coal in the eastern and western parts of Canada, but the cost of conveying it to points where coke is needed for smelting purposes is prohibitive. On the other hand, there are a great many water powers throughout the provinces of Quebec and Ontario where electricity can be developed and utilized. If the electric system proves to be commercially feasible Canada is looking for the inflow of a large amount of capital and considerable mining development.

The Kjellin electric steel furnace at Gysinge, near Stockholm, Sweden, has been in operation since 1899, and it is claimed the process will bear comparison with the crucible and open-hearth furnaces in production on a large scale. The record shows that about 5,000 kilos of ingots are cast in twenty-four hours, or a little over 12,000 pounds. This furnace is chiefly employed in the regular production of tool-steel. The specialties manufactured at the Gysinge works are drills and chisels, forged stamping tools, steel forgings and forged steel for gun barrels, magnets, etc. The special qualities of this steel are its great elasticity, absolute homogeneity, softness and the high proportion of carbon, together with its excellent magnetic properties.

The magnitude of the metallurgical industries of this country is truly amazing, but time will not permit me to give you statistics except in a very limited way.

It is stated that we are turning out 41 per cent. of all the steel made in the world to-day, and still we are not making enough for home consumption. The imports of iron and steel for the last fiscal year exceeded $23,000,000.*

Even in secondary or subsidary operations, which do not attract general attention, we hold a leading position among the civilized nations. Let us consider for a moment the case of the galvanizing and tinning processes, and we will find amazing figures of tonnage.

In a recent article by Chas. F. Burgess in the *Electro-Chemical and Metallurgical Industry* on "The Action of Acids on Iron and the Use of the Acid Pickle," the following interesting statement appears: "Pickling constitutes an essential step in the well-known galvanizing process. Prior to immersing the sheet metal in the molten zinc it must be freed from scale and other oxides, and this is most satisfactorily accomplished by the use of the acid dip. To show something of the magnitude of this operation alone it may be estimated that since 60,000 tons of zinc per annum are used in this country for galvanizing, the area of surface which is thus protected is approximately equivalent to seventy square miles, or 40,000 acres. The area which must be pickled in the manufacture of wire and sheet metal probably largely exceeds even this. Statistics show that about 1,500,000 tons of iron and steel wire were produced in 1903. Such an amount of iron in the form of wire posseses over 100 square miles of area, and since the process of pickling must be repeated several times during the operation of drawing, the pickled area is unquestionably larger than this amount. From figures taken from the United States Census Report for 1900 about 20,000,000 pounds of tin were used for the production of tinned sheets, and this again represents a second area of about

*The production of pig iron in the United States, according to the annual statistical report of the American Iron and Steel Association for the year 1904, was 16,497,033 gross tons. The latest estimates indicate that the furnaces are now making pig-iron at the rate of nearly 30,000,000 tons a year. Ten years ago the production was considerably less than half this amount.

140 square miles which must be pickled, not once, but twice."

I call attention to this statement in order to show the magnitude of galvanizing and tinning operations in the United States.

A comparatively new method of pickling iron castings to remove sand is to immerse them in a pickling bath containing hydrofluoric acid and water. Hydrofluoric acid dissolves sand while sulphuric acid dissolves the iron and does not affect the sand, merely loosening it. Experiments which I made some years ago in pickling cast-iron test bars in both acids showed that the sulphuric acid pickle caused a loss in strength and ductility of the bars averaging nearly ten per cent., while bars pickled in hydrofluoric acid were not appreciably weakened thereby.

THE METAL OF THE FUTURE.

A recent dispatch from Washington to *The Iron Age* says: "The production of aluminum in the United States has increased nearly ten fold in as many years, according to the annual report of the U. S. Geological Survey for 1904, which has just been completed. Two reasons explain this phenomenal growth—economic production, which has initiated low prices, and increased consumption, especially in the electrical industry. The output of 1904 was 8,600,000 pounds as compared with 7,500,000 pounds in 1903. When it is remembered that the industry dates its beginning from 1883, in which year the production was 83 pounds, its rapid development will be appreciated. It was not until 1891 that the output reached 100,000 pounds. but from that date the output has been phenomenal.

Aside from the electrical industry, in which aluminum is gaining favor as a substitute for copper conductors for the electric transmission of light and power, there has been expansion in other directions. The steel industry has become an important consumer of aluminum. Usually from two to five ounces of aluminum are employed per ton of open-hearth steel made, and from six to eight ounces for Bessemer steel. If every ton of steel manufactured in the United States in 1904 had been subjected to this treatment there would have been about 5,000,000 pounds of aluminum consumed.

Among other uses of aluminum may be mentioned parts of looms and other vibrating or moving machines, household and

military utensils, lithographic plates, alloys with copper, zinc and other metals, motor-car fittings, chemical vessels, &c."

A practical method for plating aluminum on iron would be a valuable discovery. In this connection I cannot help alluding to the fraud that was perpetrated upon the City of Philadelphia some years ago, when thousands of dollars were paid ostensibly for plating the iron work of the great tower on the City Hall with aluminum. It was claimed that this light-gray colored metal was heavily plated on all the iron work and that it would retain this color, closely resembling the stone base of the tower indefinitely without further attention. The black appearance of the iron of the tower, and its serious injury by reason of oxidation, is a sufficient proof, if such were needed, of the falsity of these statements. I believe I am correct in saying that there was no known method by which the iron could have been protected by a galvanic coating of aluminum at that time, and I doubt if it would be possible even at this day. Aluminum being a highly electro-positive metal does not lend itself to the process of electro-plating.

CONCLUSION.

I have endeavored to give you as brief a survey as possible of the field covered by metallurgical industries and of the progress made therein since my last address a year ago.

I am conscious that I have merely touched upon a few themes, and have neglected many others of perhaps equal importance. Yet I have occupied more of your time than I intended to do. I hope, however, that I have not wearied you, and I wish to thank you for your attention, and to congratulate you upon the prospects before you in the large number of important papers which the program announces for the winter course, all of them by men of recognized ability in their profession.

ELECTRICAL SECTION.

(Stated Meeting, held Thursday, October 12, 1905.)

Electrolytic Copper.

By Lawrence Addicks.

[The author here discusses the subject of the electrolytic refining of copper, especially from the point of view of the multiple system of refining.—The Editor.]

The advent of the dynamo made electrolytic copper at once possible and necessary. The consumption of copper pursuant upon the generation and transmission of electric power in quantities never dreamed of in the days of primary batteries, has many times exceeded the output obtainable from the few sources of the native metal which will yield a product of satisfactory conductivity without electrolytic treatment.

The fact that certain mines in the region of the Great Lakes yield a mineral so free from objectionable impurities that a high grade copper is obtainable directly by a simple furnace scorification, early gave Lake copper a premium in the market that electrolytic competition even yet has not entirely wiped out. For almost all purposes there should be no hesitation whatever to-day in specifying electrolytic copper. In conductivity it is superior to nearly all brands of Lake, and in mechanical properties it leaves little to be desired. There are a few classes of work in which the metal is subjected to very severe punishment, such as in the making of cartridges, where Lake seems to stand up better than electrolytic, although even here it is a question how much to allow for the trade prejudices of the older generation of mill foremen who clung so tenaciously to the perplexing system of wire gauges of but a few years past. Any such advantage in Lake copper must be attributed to the fact that it is not so clean as electrolytic. A small quantity of arsenic, for example, while exceedingly detrimental to the conductivity, will appreciably improve the mechanical properties of

copper. At one time arsenic was considered necessary in English specifications for firebox copper. Each year a greater proportion of the world's output is electrolytically refined, and it seems probable that before long there will be but two grades of copper on the market—high conductivity copper, which will include electrolytic and picked brands of Lake, and casting copper, covering all material which will not pass a conductivity requirement of 98 per cent. annealed.

The ideal electrolyte for refining copper would be one chemically inert as a solvent but capable of electrochemically dissolving copper, and of zero specific resistance. These conditions are most nearly met by an acidulated sulphate solution, and this has the additional commercial advantage of employing one of the cheapest of chemicals, sulphuric acid. A sufficiently high percentage of sulphuric acid may be carried to make the specific resistance very low. There is a slight redissolving of the cathode copper, but not in serious amount. Gold is untouched and silver practically so. It is customary to carry a minute percentage of some soluble chloride as a constituent of the electrolyte which would throw down as chloride any silver which might be dissolved and also tend to slime antimony as oxychloride. Some claim that smoother cathodes result from the presence of chlorine. While the actual benefits from this ingredient are open to question, it certainly does no harm, and the refiner is often morally sustained by its presence.

In American refineries high grade anodes are universally used. Usual compositions are:

Copper	98 to 99.5 per cent.
Silver	0 to 300 ozs. per ton.
Gold	0 to 40 ozs. per ton.
Arsenic	0 to 2 per cent.

Small amounts of antimony, bismuth, iron, nickel, sulphur, selenium, tellurium and silicon.

Impurities with soluble sulphates go entirely into solution and grow cumulatively. Selenium and tellurium and the precious metals go entirely into the slimes. We have therefore a triple separation. The usual products are only copper at the cathode, silver and gold from the slimes, and sometimes copper and nickel sulphates from the electrolyte. Selenium and tellurium, especially the

latter, are easily recoverable from the slimes, were there sufficient market. Tellurium is an element almost without use in the arts. Small amounts are used in medicine, but the output of one of our copper refineries for one day would stock a large chemical supply house with tellurium enough to last a year. Arsenic, antimony and bismuth go partly into solution, partly into the slime, depending on the nature of the form of combination in which they exist in the anode and various secondary reactions taking place in the electrolyte.

Arsenic is the most difficult impurity with which to deal. If much is present in the anode, say over one per cent., it rapidly grows in the solution and necessitates a large expenditure for purifying to hold it down. With small quantities it seems to slime more rapidly and no purifying at all is necessary. With other conditions properly cared for, satisfactory cathodes can be produced in an electrolyte running two per cent. arsenic, though this is considerably above the customary figure.

The purification of solutions is almost always done by working up a certain quantity regularly into bluestone and adding fresh acid to the electrolyte. If the purification requirement is heavy the bluestone department becomes disproportionately large, and consequently copper running high in arsenic is most unwelcome. Antimony and bismuth are seldom present in sufficient quantity to cause trouble. Various chemical methods of purification have been tried with the object of regenerating the electrolyte and returning it to the circulation, but there are few substances that will precipitate arsenic in an acid solution, and further the action of such reagents does not seem reliable, probably due to differences in form of arsenic compounds present at different times. For example, the writer has boiled electrolytes running high in arsenic with metastannic acid* and obtained a remarkable cleansing action and upon other trials, found hardly any precipitation.

The insoluble anode slime from which the gold and silver are recovered is very variable in composition, as might be expected, depending on the grade of material being handled. It is chiefly metallic in nature and a common composition would be as follows:

*U. S. Pat., No.———. F. B. Badt.

Silver	40 per cent.
Gold	2 per cent.
Copper	25 per cent.
Selenium and Tellurium	5 per cent.
Arsenic and Antimony	10 per cent.
Lead, Silica, Sulphuric Acid, etc.	18 per cent.
	100 per cent.

The presence of so much copper in the slime is objectionable in the silver refinery process and must be removed before cupelling the dried slimes to avoid making very rich slags. The other impurities give but little trouble, except possibly tellurium, which requires prolonged furnace treatment to burn it off. The copper is present in very finely divided form, as is shown by experiments in fine screening to reduce the copper contents. Almost all of the copper which will pass a 40-mesh wire screen will also pass a 200-mesh. This would indicate that the coarser screen removes the fine crystals that have dropped from the cathodes and that the remainder is in the form of a chemical cement. Wohlwill's experiments* indicate that this is due to the formation of some cuprous sulphate at the anode with subsequent oxidation to cupric sulphate and the liberation of metallic copper.

$$2Cu' = Cu'' + Cu$$

The amount of cuprous sulphate formed is a problem in chemical equilibrium dependent upon many factors. The copper dust is usually removed by leaching it out in hot concentrated sulphuric acid, taking care not to carry the action too far, as this would result in dissolving some of the silver. If a more rapid reaction is made use of, such as that with ferric or silver sulphates, the copper is dissolved almost immediately, owing to the enormous surface exposed.

The cathode copper is exceedingly pure, usually running about 99.93 per cent. copper, with hydrogen as the chief impurity. Objectionable cathode impurities are of two classes—those which depress the electrical conductivity and those which make the metal brittle. Arsenic and antimony represent the first class; tellurium and lead the second. Good cathode copper should show but a few thousandths of a per cent. of arsenic and antimony. The writer's experiments have indicated that

*Zeitschrift für Elektrochemie, April 23, 1903, p. 311, *et seq.*

it takes but 0.0013 per cent. of arsenic or 0.0071 per cent. of antimony to lower the conductivity one per cent. Any conductivity troubles in electrolytic copper can almost invariably be traced the presence of undue amounts of one or both of these elements. Impurities of the brittle-making class are very rarely met with, and if present are due to mechanical contamination of the cathode, either in the bath or in the subsequent furnace treatment. A third class of cathode impurity concerns the refiner, comprising silver and gold. Cathodes usually show from one-tenth to one ounce of silver and a trace of gold.

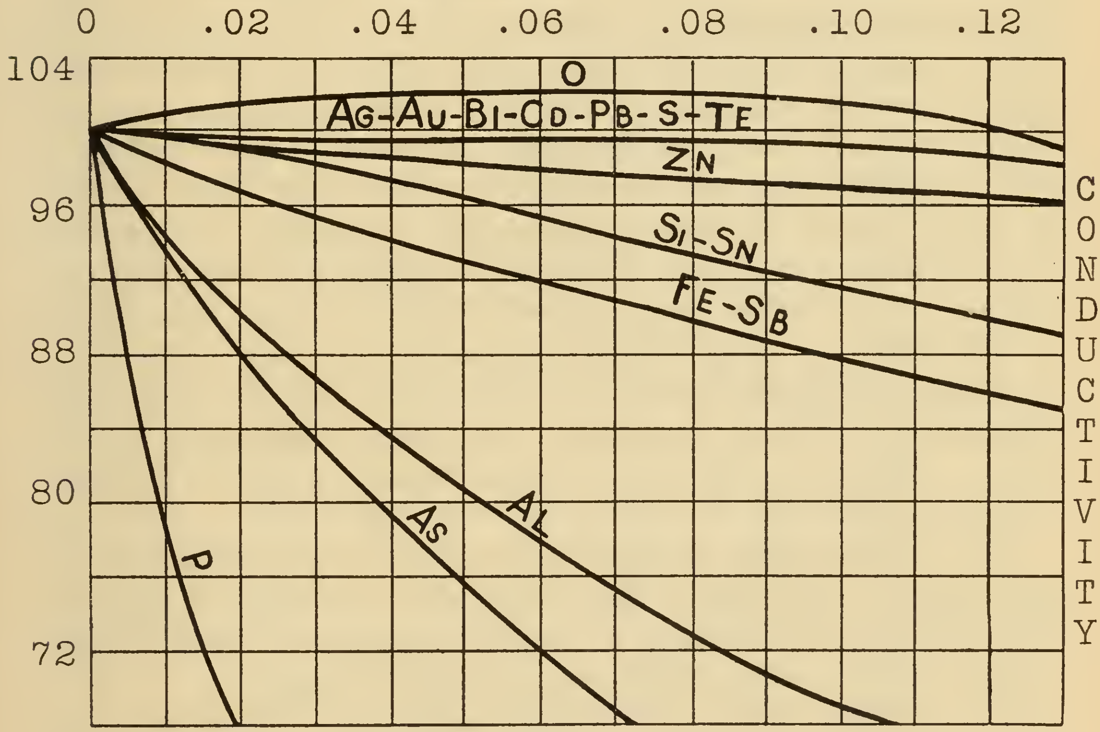

Fig. 1

This seems to be due entirely to the mechanical fouling of the cathode by particles of anode slime. In fact, it is a question if most of the arsenic and antimony found in the cathodes does not have a similar origin. The slime is very finely divided and the continual circulation of the electrolyte necessary to prevent polarization maintains a very slight turbidity. These particles are probably electrostatically attracted to the cathode. Fig. 1 shows in a general way the effect of various impurities on the electrical conductivity of copper.

The output of a refining tank depends upon the total current

passing through it, the number of electrodes in series, the time the current flows and the electrochemical equivalent. In the present case the theoretical amount per ampere day per pair of electrodes in series is almost precisely an avoirdupois ounce. The amount actually deposited is always less than this, due to chemical solution of the cathode, grounds and short circuits between electrodes. The redissolving of the cathodes will amount in practice to 0.5 to 1.0 per cent. of the amount deposited. This action is chiefly at the surface of the bath. In the presence of oxygen, copper is slowly oxidized to cupric sulphate by sulphuric acid.* The reaction is quickened by heat but in so far as the writer's experiments extend, is independent of the composition of the electrolyte. Metallic copper is also slightly soluble in cupric sulphate.† If the tanks are well insulated from the supporting piers, and care is taken to break the circulating pipes carrying the electrolyte from tank to tank, by either rubber sections or miniature waterfalls, the current shunted around the tanks by grounds should not average over one per cent. of the total. Short circuits between electrodes, caused either by direct contact between anode and cathode or by indirect contact between the electrodes and the tank, will amount to some five per cent. under best commercial conditions. In this way the net current efficiency is usually from 90 to 95 per cent.

The voltage at the switchboard required to force the current through the tank-house depends upon a number of factors. The resistance is made up of metallic resistances, liquid resistances, contacts and counter-electro-motive-force.

The metallic resistances can be figured on Thomson's law that the cost of power lost should equal the interest on the investment in copper. As the continuous operation gives a load factor of 100 per cent. the rule can be applied without the usual allowances. As regards the investment, the copper can be considered as so much extra metal tied up in the process. Any density under 1000 amperes per square inch will run cool enough.

The liquid resistance of the electrolyte is largely influenced

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*Electrochemist and Metallurgist, April, 1902, p. 103.

†Zeitschrift für Elektrochemie, April 23, 1903, p. 311, *et seq.*

by its chemical composition. Fig. 2 shows the approximate specific resistances of electrolytes carrying varying amounts of copper and free acid. The conductivity of an electrolyte depends upon the number of ions present, the speed of migration and the charge of electricity each carries. The charge carried

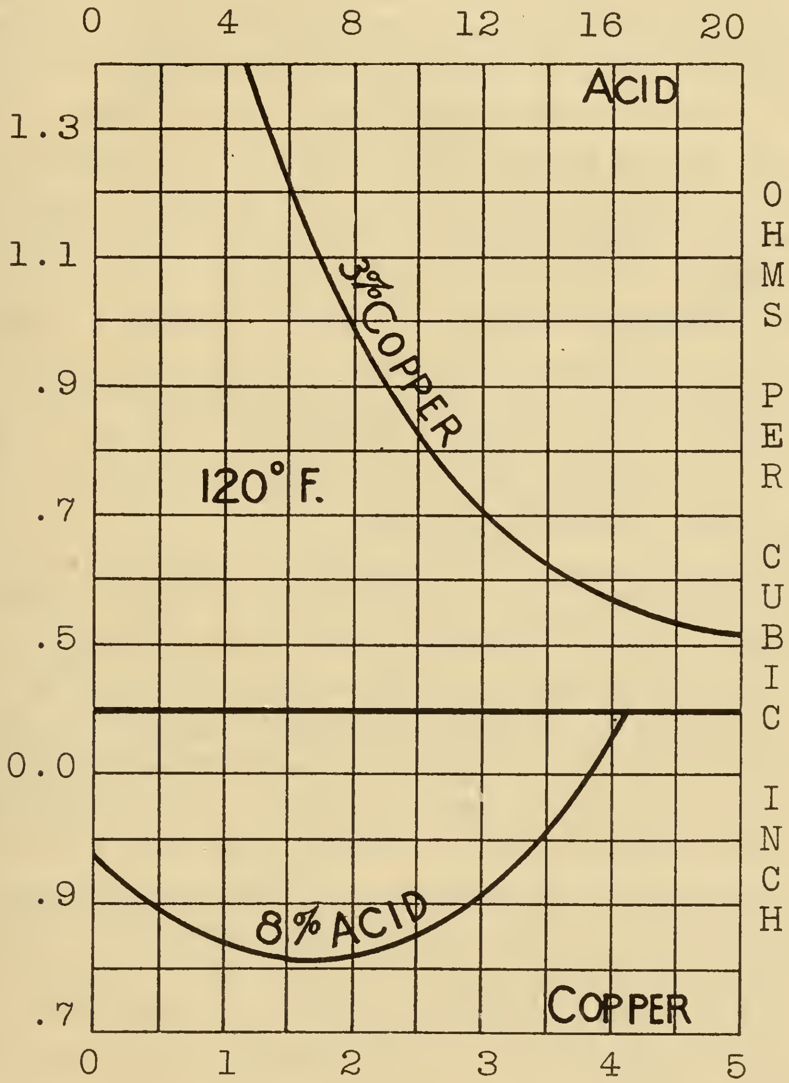

Fig. 2

is a constant for the various compositions as the valency does not change. The ions concerned are copper, hydrogen and sulphion. Hydrogen is much the swiftest of these and hence the effect of the free acid present in lowering the resistance. The number of ions present depends upon the concentration

and the degree of dissociation. In this case we have a mixture of two electrolytes with a common anion, SO_4, and the proportion of one present controls the degree of dissociation of the other. This is shown in the curve giving the effect of varying the copper contents of the solution. Starting with a fixed percentage of free acid present, additions of copper sulphate at first increase the conductivity due to the increased number of ions present. After a certain quantity of copper is reached, however, further additions have the reverse effect. This is due to the driving back of the dissociation of the acid by the increased proportion of the SO_4 ions claiming a copper mate in accordance with the laws of equilibrium. It will be seen from these data that the copper should not exceed three per cent. at the most, or twelve per cent. if figured as bluestone. The acid may advantageously be run up to about thirteen per cent. If carried higher, polarization troubles are likely to offset the gain in conductivity. These figures are for pure electrolytes. In practice impurities cause the resistance to be ten to fifteen per cent. higher than shown.

Transfer resistance is the name which has been given to a liquid resistance, the nature of which is not fully understood. If we make a series of measurements of the voltage drop between a pair of electrodes at varying current densities, Ohm's law requires that a current-voltage plot should be a straight line. Where this line cuts the ordinate of zero current is a measure of the counter-electro-motive force present. If we analyze the results, however, we shall find that the indicated specific resistance of the electrolyte is higher that it should be, and that the discrepancy is greater the nearer were the electrodes spaced during the measurements. These facts are illustrated in Fig. 3, and indicate a high ohmic resistance near the electrodes. Exploration of the potential gradient between anode and cathode with a potentiometer confirms this and shows that it exists at both electrodes.* The most probable explanation seems to be that there are minute bubbles of gas in the neighborhood of the electrodes, due to slight generation of hydrogen and oxygen. The phenomena can also be explained by assuming that there is an irreversible polarization present,

*Transactions American Electrochemical Society, Vol. vii, p. 51.

which is a function of the current.* The transfer resistance is greatest in the high acid electrolytes and at low temperatures. Its practical effect is to reduce the gain to be expected by spacing electrodes close together and from increasing the acidity of the electrolyte, and to increase the gain to be expected from heating the electrolyte.

The temperature co-efficient of electrolytes is large and varies with the temperature. Fig. 4 shows the effect of tempera-

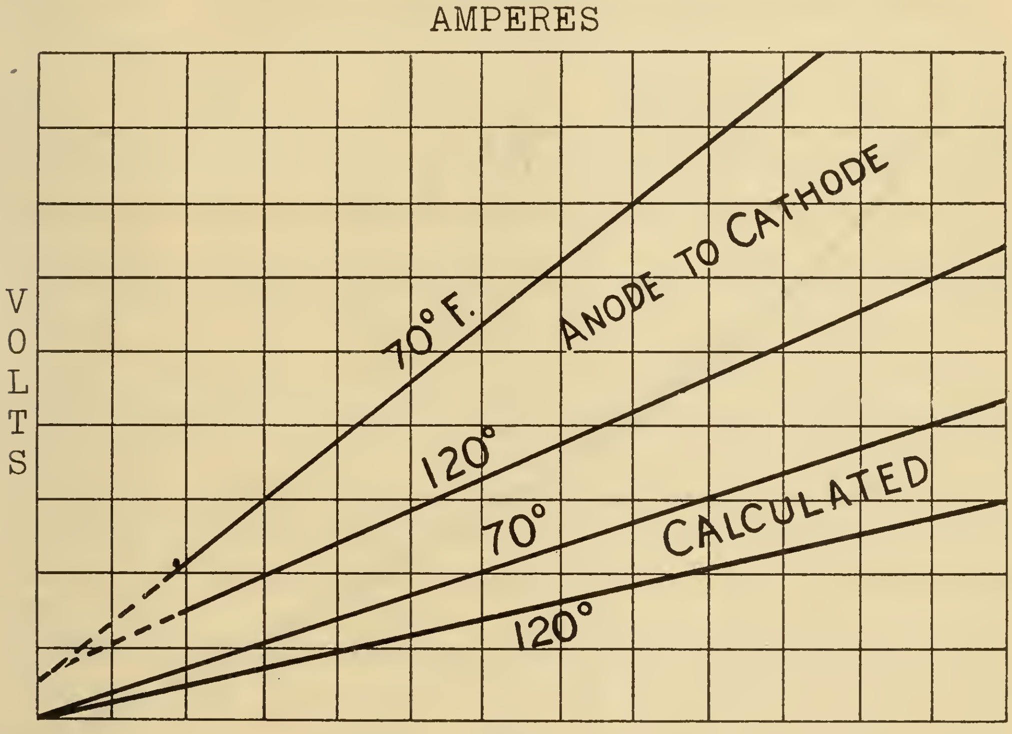

Fig. 3

ture change on a typical copper refining electrolyte. The practical effect of the change in temperature upon the resistance is rather complex. The transfer resistance exhibits a very large temperature coefficient while the contacts and metallic conductors are not appreciably affected. The resultant coefficient figured from the switchboard is approximately 0.5 per cent. per degree Fahr.

Contact resistances are met with at the joints in the main bars and at the connections between bars and electrodes. The joints in the main bars should be equal in conductivity to the bar itself. This standard can easily be attained if the bars are

*Transactions American Electrochemical Society, Vol vii, p. 33.

properly faced. Three or four hundred amperes per square inch of bearing area will give no trouble. The contacts between the electrodes and the main bars are very variable. A single contact will run from 0.000005 to 0.0005 ohm, according to the cleanness of the engaging surfaces and the pressure.

Finally we have a certain amount of counter-electro-motive force present due to the greater concentration of the electrolyte at the anode than at the cathode. This is in general very small, —about 0.02 volt per tank in the multiple system. The anode

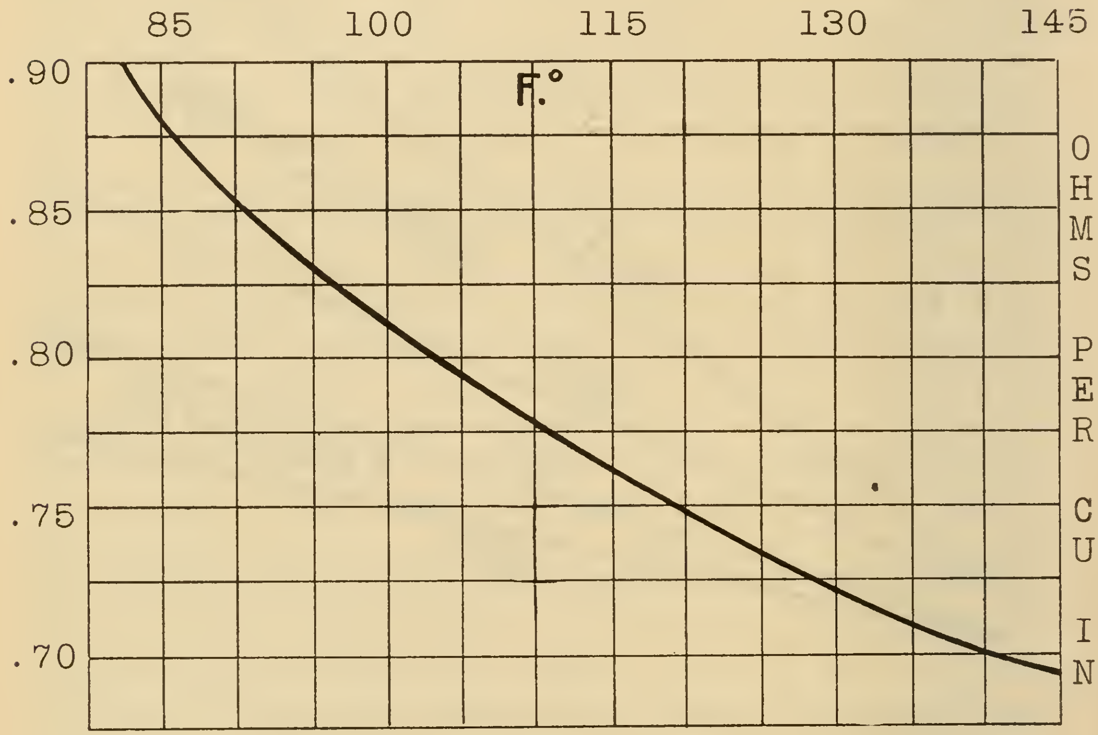

Fig. 4

slimes cause a certain amount of polarization, and if very bulky and adherent it may become serious, starting intermittent gasing and making the tank "crazy."

Tank resistance is therefore made up of a number of factors and, as none of the power applied is absorbed chemically, disregarding the small counter-electro-motive force, it is possible to make any of these factors as small as desired, and it is a commercial problem to determine the most profitable value for each. A rough summary of the relative values of each in practice is as follows:

Metallic resistance	15 per cent.
Electrolyte, including transfer	60 per cent.
Contacts	20 per cent.
C. E. M. F.	5 per cent.
	100 per cent.

The question of what current density to carry is largely one of power cost. Present American practice runs all the way from twelve to thirty-five amperes per square foot. The steady full load on a large power-house gives ideal conditions for the generation of cheap steam power. With high-current density the tank room requires much closer supervision, as there is a greatly-increased tendency toward polarization. It is customary to circulate the electrolyte from tank to tank to maintain uniform composition throughout. If this were not done the heavy liquor from the surface of the anode would form a horizontal layer of increased specific gravity at the bottom of the tank. Different strata would then have different conductivities, crystals of blue vitriol would form on the bottom edge of the electrodes and the operation of the tank be thoroughly disorganized The higher the current density the greater this tendency and the more active must be the circulation. An excessive circulation tends to stir up the silver mud and results in an increased silver loss in the cathodes. It is safe to say that roughly, the silver contents of the cathodes made at a density of thirty amperes per square foot will be double that of cathodes made at half the density. High-current density also means rougher deposition and necessitates more frequent renewal of the cathodes to maintain the current efficiency. Most of the Eastern refineries run at from seventeen to twenty amperes per square foot.

The size of tank is chiefly a matter of construction. The number of electrodes placed in parallel does not seem to bear any direct relation to the current efficiency. This is probably because low efficiency is caused rather by the condition of the deposit or its tendency to sprout and form trees than by local mechanical troubles between single pairs of electrodes. Sixty electrodes in a single multiple tank give no trouble. Various dopes have been tried for controlling the character of a deposit. Ammonium sulphate undoubtedly exerts a beneficial effect in

encouraging smooth deposits. This may be due to some secondary cathode reaction in which the ammonium radicle is momentarily freed. Ammonium sulphate increases the resistance of the solution, however, by driving back the dissociation of the free sulphuric acid present. Organic reducing agents, notably gelatin, have marked effect in restraining the crystalline nature of deposits, but are not easily controlled in copper solutions. The peculiar structures sometimes seen at the cathode are doubtless due to the effect of various soluble impurities in the anode. Often a total change in the character of a deposit can be induced by simply lowering or raising the temperature of the electrolyte.

Comparatively little copper is put upon the market in cathode form, although this is an ideal shape from which to make brass and copper castings. The wire bars and ingots never give a conductivity equal to that shown by samples from the cathodes from which they are made. This is partly due to the absorption of some impurities from the furnace lining and products of combustion, and partly to mechanical pocketing of impurities in the cathodes during the electrolytic process. These particles of impurities are associated with nodules and a smooth part of the cathode is naturally selected as a sample to draw out into wire.

The furnace operation consists in melting down the charge rapidly in large reverberatory furnaces and exposing it to an oxidizing treatment until the bath contains about 6 per cent. of cuprous oxide in solution.* This exerts a strong scorifying action on such impurities as can be slagged. The metal at this stage exhibits a characteristic fracture and is called "set" or "dry" copper. Carrying the oxidation further only results in needlessly slagging copper. The reaction is then changed to a reducing one by means of hydrocarbon gases evolved from green poles thrust beneath the surface of the bath and the copper brought back to "pitch," or when it contains some 0.6 per cent. of cuprous oxide, and gives castings the surface of which neither rises nor falls when "setting" in an open mould. The metal in this state develops the best mechanical properties under subsequent treatment. Underpoled copper simply con-

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*Transactions American Institute Mining Engineers, Vol. xxxiv, p. 671.

tains an excess of cuprous oxide as an impurity and suffers in both electrical and mechanical properties. Overpoled copper looks like slightly underpoled copper under the microscope. The mechanical properties are satisfactory, but there is a slight decrease in conductivity and castings are bad, due to the expulsion of gases as the metal sets. An overpoled bath is, however, in a very unstable condition, and it is usual in such a case to start at the beginning of the refining operation and oxidize the metal to set copper again. The chemical reasons for these facts are not fully understood. The fact that molten copper is so sensitive chemically to its surroundings, and that it chills so readily, due to its high thermal conductivity, makes it a difficult metal to handle.

This paper has been written from the point of view of the multiple system of refining. The main points of difference between this system and the series system are in power cost, compactness, and cost of preparing anodes. The power required is practically half as much again in the multiple tank. The series tank has relatively no contacts or conducting bars and the electrodes are very close together, the anodes being thin even plates. To produce such anodes they must be either rolled or specially hand-cast, and the grade of material used must be good. The interest on the metal tied up in process and on the investment in plant is less in the series system. The series system requires no starting sheets, but much closer supervision to keep the quality of the cathodes up. As lead-lined tanks cannot be used in series work, due to the relatively high voltages used, tank maintenance becomes an important item. The fact that large refineries on both systems are being satisfactorily operated bears witness to the close balancing of the pros and cons in each case, although much more material is refined by the multiple than by the series process.

THE JOHNSON SYSTEM OF SELECTIVE WIRELESS TELEGRAPH.

The British Admiralty proposes offering facilities to A. T. Johnson for testing his selective system of wireless telegraphy upon a practical working basis at sea. The characteristic feature of this invention is that when a message is dispatched to a certain point it is impossible for it to be received

by any other than the requisite station, neither can it be intercepted or dispersed during transmission. In this device the inventor utilizes in his transmission apparatus the ordinary Ruhmkorff coil. On the base of this, however, is attached a reed disk. Armatures provided with weighted heads are fitted to this disk, and carry tuning reeds. The electric contact is made in the usual manner. The receiver comprises permanent magnets, strengthened with electro-magnets, and with an arrangement of steel reeds similar to those fixed to the transmitter, and with those on which they can be timed in unison. In transmitting a message the operation at the transmitter revolves the reed disk until the timing reed and its speaking reed are brought immediately in front of the center cone or cones of the electro-magnet. The contact pillar is then placed in connection with the speaking reed so that the vibrations thereof cause synchronous vibrations in the timing reed, which is the indicator. The vibration of this latter reed indicates to the transmitting operator that his companion at the receiver is getting the message satisfactorily, since the indicator must vibrate in unison by the law of syntonic synchronism. Experiments are being made in London with the system daily, and so far have proved successful. It would seem, however, that the great difficulty would be to obatin perfect unison in two stations situated at great distances from one another owing to the liability of the reeds being affected by climatic and temperature conditions which are constantly varying.—*Scientific American.*

THE KNOTH STEEL PROCESS.

Henry Knoth, superintendent of the steel plant at Monterey, Mexico, in a recent patent (U. S., 788,650) proposes that the liquid slag (resulting from an initial heat prepared in the usual manner in a basic open-hearth furnace) be used continually to purify other heats by being returned to the same furnace, the losses in the basic properties of the slag, by continually purifying heats, being replaced by lime or other fluxing materials. Preferably, the unpurified metal (to be acted upon by the molten slag) is introduced into the furnace in a molten condition; or better, blown in an acid converter, in both of which cases the bath, due to the ready condition of the slag, will go at once into action, and the duration of the heat will be considerably reduced. This process is being extensively used at the Monterey Steel Plant, where it is said to be giving excellent results.

The process is intended to operate most successfully when the pig metal is treated in an acid converter; it is claimed that (where the unpurified metal is blown in the converter to 1 per cent. carbon, and then charged into an open-hearth furnace and treated in accordance with the Knoth process) a production of 200 tons of steel in 24 hours can be easily obtained from a 30-ton furnace.

Among the other advantages claimed for the process are the short time of the heats in the furnace, and accordingly the increased life of the furnace hearth, the opportunity to repair the furnace bottom between heats without interrupting the continuity of the process, and the utilization of all the basic properties in the slag.—*Eng. and Min. Jour.*

THE FRANKLIN INSTITUTE

(Stated Meeting, held Wednesday, October 18th, 1905.)

Thermit Practice in America.

By E. Stütz.*

Member of the Institute.

[In this communication, the author gives a somewhat detailed account of the progress made within the past eighteen months, in the introduction in the United States of the Thermit process as applied in various engineering and mechanical arts. The progress has been rapid and apparently the process has proven quite as successful here as abroad.—The Editor.]

It gives me particular pleasure to address a meeting of the Franklin Institute, as it was in this hall that some twenty months ago an opportunity was offered me to explain the possibilities of the alumino-thermic process, which had been developed beyond the experimental stage on the continent of Europe, but which was practically unknown in the United States at the beginning of 1904.

The subject was so new that it did not attract the attention which we (with our greater knowledge of it) thought it deserved, but this impression was dissolved by actual experience. As I went further over the country with the object of introducing the process, I was surprised at the number of men whose acquaintance was important for my purpose, to whom my face was familiar just from this Franklin Institute lecture, so that I may well say that I have seldom talked before so thoroughly representative and competent a gathering.

I am still more pleased to be able to say personally in this place, how highly Dr. Hans Goldschmidt has appreciated the signal distinction conferred on him by this Institute, through the award, by the Committee of Science and the Arts, of the

Elliott-Cresson Medal. Not only did he very highly appreciate this compliment—the first paid him in the United States—but it encouraged all of us who are connected with the process in this country to continue his work of organizing and developing the numerous new applications in metallurgy and engineering to which the fundamental discovery of the self-continuing reaction between finely-divided aluminum and metallic oxides has opened the door.

When we showed this process of creating 5400° F. by igniting a powder in a suitable vessel, here on this floor (which was protected only by some sheets of asbestos and one layer of brick and sand) we proved that we had a power at our disposal and entirely under our control, which, through the extraordinary speed at which it developed and the wonderful simplicity of the apparatus by which it was controlled, afforded a means of producing results which until then had never been thought possible. Nobody could fail to be impressed by these facts, but naturally the human mind, in all its variations, had still to be guided in the proper direction in which the new power could most advantageously be utilized. The shallow mind saw nothing in the display but a new sort of fire-works. The hypercritical mind saw only the possibilities of non-success. The enthusiast wanted the process used for making anything and everything—from an armor plate ingot to a pin. The man who is always in a hurry thought it too complicated because it was not a machine, ready for use, but required brains, care and perseverance to properly understand and handle it. This latter point—teaching the people to understand the process—has been our principal object and our principal difficulty. There are persons who cannot learn because their minds run in grooves, and there are others who will not learn, because they think that they know better. Both are very likely to attribute non-success in any operation—not to themselves, but to the process.

As it is, the alumino-thermic process does not fit into any of the traditional divisions of the arts. It is a chemical invention which benefits—not the chemist—but the engineer. Some of its more important branches for uniting metals, under the present labor divisions, would fall to the blacksmith.. However, it is not a blacksmith's job, but a foundryman's.

I will not to-night show you an actual demonstration of

Thermit, because I may assume that most of you have seen the process in actual practice in some place or other. It is much more my object to tell you how various applications have been developed and turned to use for particular requirements that present themselves in their work to all classes of engineers and for which it offers them the most tangible advantages.

In January, 1904, we brought into this room two short sections of a 7-inch girder rail and we welded them. For commercial reasons it was not found possible to actually do these welding operations on the track until six or seven months later. It was commercially impossible to do such work until we manufactured Thermit in this country, for which purpose an installation was completed in July, 1904.

In this field of track work we were new-comers and competitors of some established forms of joining rail ends for street railways by either an electric-welding or a cast-welding process. The so-called "cast-welding process," which consists in running a heavy sleeve of liquid cast-iron around the end of the rail, had been very successfully introduced and exploited during a period of about ten years. It was at that time undoubtedly the best form of obtaining a continuous rail, and when the work was done under favorable conditions and with great care, it showed satisfactory results. It is hampered, however, by the necessity of melting its iron in close proximity to the track, and therefore has to carry around a large and cumbersome cupola on wheels. The cast-iron has to be carried, by two men, in ladles, along the track, from the cupola to the joint, and poured into cast-iron molds. In order to obtain the desired cohesion between the sleeve and the rail ends, it is necessary that the latter be very clean and free from moisture, and that the amount of liquid metal be very large indeed, in order to develop the necessary temperature. For girder rails, the weight of this sleeve is therefore between 180 and 200 pounds. The weight of such an anvil at any point of the rail has a bad influence on the evenness of wear of the track, and this disadvantage is increased when the anvil effect takes place at the joint.

Against this process we took the field with the small crucible (about fifteen inches high) in which, in half a minute, we produce a quantity of eight to ten pounds of highly super-heated liquid steel, which we could run directly around the rail ends.

With these ten pounds of super-heated steel, at a temperature of about 5400° F., we obtained an absolute fusion of the rail material with our own steel.

We have to melt just the quantity of steel that suffices for each joint. We need not wait until we have some seventy or eighty joints ready for operation, at the risk of losing a large part of the metal in case of an interruption, but we can take each joint separately and the efficiency will always be the same. We obtain the result by an absolute fusion of the rail ends with the small shoe of thermit steel, and in doing so, obtain an absolutely solid joint with an increased area of electrical conductivity. Our whole outfit consists of this crucible, with welding

Fig. 1. Rail welding at Cleveland, showing mold in position.

portion which contains the necessary amount of Thermit for each particular section of rail and the pair of mold boxes (also made specially for each section of rail) which exactly fit the section from either side. The molds are made in a sheet-iron box, of a mixture of sand and clay or sand and flour, and tamped over a wooden model, so as to get the exact outline of the steel shoe that is to be fused on. These molds require great exactness of detail, so as to have the necessary amount of steel properly distributed over the whole welding surface. The mold is the most essential part of the equipment. It must

be carefully made, so as to be porous and dry. Being of a somewhat fragil material, it requires careful handling in fitting it to the rail, which should previously be heated to drive out the moisture. It must be kept covered until the operation actually begins, to prevent any dirt or sand from dropping into it, and it must be extremely carefully luted at all contact points with the rail, so as to prevent any leakage. The importance of preventing a leak arises not only from the loss of the thermit steel, but also from the loss of metal it is intended to weld. The hot steel running out of the crucible, through the gate and around and up the web of the rail, will melt the material with which it comes into contact and liquefy it. The momentum

Fig. 2. Rail welding at Cleveland, showing Thermit reaction.

with which the steel drops down into the mold will necessarily carry a part of it up through the mold. A leak that develops will then drain out—not only the thermit steel itself, but also the metal of the rail with which it has come into contact, and leave an ugly hole in its place. It is not that the rail has been burnt in this place, but simply that the scouring action of the super-heated steel has washed away the original metal, with which it would have been combined to one homogeneous mass if it had been prevented from escaping.

Some thirty cities in the United States have tried this pro-

cess up to the present, some 13,000 joints having been welded —some on a large scale, like Cleveland, Ohio, where about 3,000 joints were put in this year, after a sample quantity that stood through last winter, and Holyoke, Mass., where about a thousand points have been put in after the same test of 160 joints last year.

In both cases the street railway company trained its own men in the application of this process, which they operate quite independently from the Goldschmidt Thermit Company, buying from them only the necessary quantity of welding portions and the necessary number of crucibles. They have trained their

Fig. 3. Nine-inch welded rail.

"gangs" of four men, who will in the course of a day make about thirty joints. They make their own molds, dry them and take them to the job in a special car set aside for this purpose. They are absolutely independent of the weather or any other adverse conditions. If the paving is delayed through an accident, it does not matter to them. They do not waste any material, whatever. If they have a small piece of track to weld, it is as economical to them as a large piece. They have the matter entirely under their control, to arrange their work as suits them best. They need not interrupt their traffic, joints having been welded on the track with cars running at ten min-

utes' headway. Once the weld has been made, there is, as a rule, no need for any grinding down, as the effect of the weld does not raise the head of the rail. The peculiarity of the process is that while the liquid steel surrounds the web and foot of the rail, the slag entirely covers the head and so brings the whole section to a practically uniform temperature. The slag does not adhere to the head of the rail, but is knocked off easily with a crow-bar. No air can get at the weld, and this is the reason why no chemical change takes place in the head of the rail. The most careful experiments have shown that the head of the rail does not get softer. Micrometer caliper measurements of the depth of indentation made by a center punch taken at the welded joint and three feet away from it showed the head of the rail at the welded joint to be, if anything, harder than the head of the rail three feet away from it. These tests were made at Baltimore.

In New York City some 300 to 400 joints have just been completed on parts of Grand Street.

It will be seen that the operation of welding rails by the thermit process has therefore been reduced to an entirely mchanical one. The mold model and mold boxes are supplied, the necessary amount of Thermit is calculated and weighed off by the Goldschmidt Thermit Company. All that has to be done is to dry the rail, place the mold, and over it the crucible, then tap the crucible. These mechanical operations—requiring certainly intelligent care—are not beyond what can be expected of a track foreman.

It is a more difficult proposition when the shape of mold and the quantity of Thermit have to be calculated by the individual operator. Such is always the case in repair work. It is not possible—even when supplied with very exact blue-prints—to always give instructions so minutely and definitely as to avoid a mistake in the construction of the mold or the quantity of Thermit. All the more is it to be admired with what thoroughness and intelligence a large number of mechanics in this country have studied the question and have obtained entirely successful results—merely by closely observing the instructions and rules laid down in the literature supplied by us. The most important case in point of that of welding frames of locomotives. These frames are of wrought-iron or cast-steel and

vary from $3\frac{1}{2}$x$3\frac{1}{2}$ to 5 x 6 inches in section. They are very liable to break and their repair without dismantling the engine means a very large saving—not only in time, but in actual labor and material. In order to repair a frame by the old methods an engine had to remain out of commission for a fortnight and the actual weld cost between $250 and $300. The work by Thermit is now done (as has been amply testified by statements of various engineers) in two days, at a cost of about $50.

Fig. 4. Welding locomotive frame.

The principle guiding the construction of the mold is that the thermit steel must not impinge directly on the casting to be repaired, but must run through the gate to below the lowest point and be made to rise from there, through and around the fracture, enclosing the latter with a strong collar, which fuses with the material of the frame. The first steel running out of the crucible into the mold, however, becomes chilled when coming in contact with the casting, which—even when pre-heated—

has a considerably lower temperature than the thermit steel. This chilling effect can only be overcome by a sufficiently large supply of thermit steel, so that the cooler part of the liquid mass is driven up into the riser and is replaced in the collar surrounding the frame by metal which has practically the full temperature it received during the reaction.

The important point in making welds by Thermit is to obtain a good circulation of the thermit steel, around and through the piece to be repaired, and after careful observation, the rule has been made that to ensure a really good weld, the quantity of Thermit should be twice that which would be sufficient to fill the actual collar which is to be welded on.

The troubles encountered in making these welds were nearly all attributed to the fact that not sufficient Thermit had been used or that the mold was constructed in such a manner that there was not sufficient vent for the air, or, finally, that the mold was either not sufficiently porous or sufficiently dry. All these conditions are absolutely essential.

If sharp sand and ordinary brickmakers' clay are used for molding material, they must be mixed in equal parts and must be *burnt* dry. To only skin-dry such molds means metal full of blow-holes, as the moisture of the back of the molds is sure to turn into steam and force its way out into the liquid steel.

For small operations, satisfactory results have been obtained by mixing ten parts of coarse sand with one part (by volume) of so-called "no grade" flour. These molds cannot be *burnt* dry, as they would go to pieces, but through the action of the steel the flour gets burnt together with the sand and carbonizes to such an extent as to protect the back parts of the mold. With molds made in such a manner, perfectly sound pours have been made in street railway work.

Wherever available, fire-brick cut down to size and carefully luted, offer a very convenient material for molds. They do not require hard drying, although even such a mold ought to be warm before being used.

Among the railways which have been particularly successful in welding locomotive frames, must be mentioned the Portsmouth shop of the Seaboard Air Line, the Elkhart shops of the Lake Shore & Michigan Southern, the Allston shops of the Boston & Albany, and the Richmond shops of the Richmond,

Fredericksburg & Potomac, records of which are available. There are a number of other lines which are using Thermit extensively, but from whom reports cannot be obtained.

Among the preliminary tests made by various railroads, I may mention one at the Elkhart shops, where a welded bar $2\frac{1}{2}''$ x$3\frac{3}{4}''$ stood a pressure of fifty tons on supports twenty inches apart, before breaking, after two sides of the reinforced collar had been machined off. It is essential that the reinforced collar be left on wherever at all practical. The original break is due to a structural defect. With the break in such a position as to necessitate the entire removal of the reinforced collar, it is too much to expect that the mere bridging of the broken ends, by means of thermit steel, would entirely overcome this weakness.

It is important, in welding locomotive frames, to allow for equal shrinkage of parallel parts, and it is also very advisable to "spring" the ends to be welded apart, before the operation, in order to let them come back when the iron begins to set.

Broken spokes of driving wheels are welded in the same manner and, as a matter of fact, a mechanic familiar with the process is able to save untold money in his shop by judicious application of the process.

Among repairs, of course the most important and most brilliant are those pertaining to marine engineering. An account of the welding of the Clyde Line steamer "Apache," of 4100 tons, will, I think, be of interest in this place.

The Apache was placed in dry dock about 1 P. M. on July 28, 1905. The dock was a graving dock, and the water was entirely pumped out at 2.15 P. M. Propeller wheel was removed and shaft drawn in to the hull, for the purpose of examining same for the benefit of underwriters. It was not necessary to remove the wheel and shaft to perform the work. The shoe or skeg had been patched. Two large plates had been placed—one on each side—and top and bottom plates had also been put on, forming a box, as it were, around the break. These were removed at 3.20 P. M. The break was found to be about $18\frac{1}{2}$ inches from the after side of what is termed the "stern post" (not the rudder post).

A mold and mold box had been previously prepared. Allowances were made in the clay mold, so that it could be fitted

tightly to the skeg. It was decided to have an aperture of clearance in the break, for the metal to flow through, and as it was impossible to spread the broken parts, a series of holes one inch in diameter were drilled vertically through the skeg—nine in number—following the line of the crack. The section to be welded measured $6\frac{3}{4}$ inches vertically by 11 inches horizontally.

Fig. 5. Welding shoe or skeg of Steamship Apache.

The men with air drills were started to drill these holes as soon as the patches were removed, and as this work would take them long into the night, after darkness set in, nothing further was done on the work the first day.

Next morning the skeg was heated to a red heat and mold box taken from the furnace and put in place. A foundation was built under the mold box, and a riser of brick, forming a base with a wall about one brick wide and about 12 inches high, was formed around the mold box, forming a basin, into which moist sand was poured. The joints were well luted and sand well packed up around the luting, so that the entire mold was thoroughly protected in case of any leaks. The mold had been so arranged, as the section to be welded was very broad (11 inches) it was thought best to have it well ventilated, and five risers were prepared, the riser box being very shallow, with a spout for the slag to run off, and a trough in the sand leading to a pit which was formed at one side.

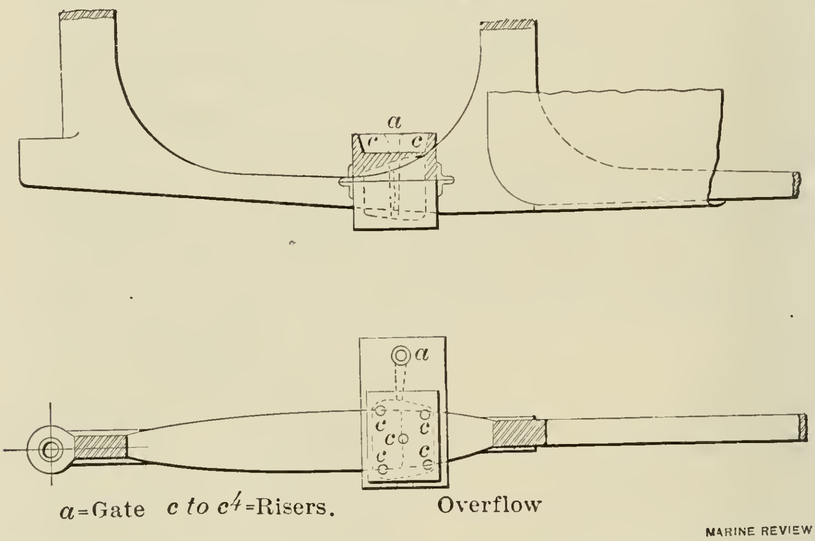


Fig. 6. Mold and mold box used in welding operation, Steamship Apache.

A small open furnace had been prepared and placed on top of the mold, in which a charcoal fire was burnt. Air from the compressed air supply on the dock was utilized for draft, and hot gas was forced down through the gate and up through the riser. While this was in progress, the crucible was put in place, the ordinary tripod being used. There were placed into the crucible 475 pounds of Thermit, together with 100 pounds of steel punchings—the punchings and the crucible having previously been heated. The mixture of the thermit, punchings and manganese was performed by pouring in each consecutively, each being well stirred as it was placed into the crucible.

Owing to the pre-heating, the final reaction was retarded

until 4.35 P. M., when the Thermit was ignited and the reaction took place. Thermit was then used in feeding to the risers and gate, feeding in gradually, maintaining continuous reaction for several minutes, to relieve the mold of gases which might form in the body of the weld. This proved to be very effective, as much gas was seen to come from the mold through the riser and gate during the feeding process. This was continued until fifty pounds of Thermit had been consumed.

The mold was allowed to remain in place over night, gradually cooling, and was then annealed by surrounding the weld with a box, in which a charcoal fire was prepared. This fire was continued about five or six hours, allowing the weld to cool gradually. In the morning when the mold boxes were removed, the gate and risers were trimmed off, and the grain of the metal appeared to be of exceptionally good quality and cut very freely with the air tools. The shaft and propeller wheel were then put in place and the vessel was ready for docking at 10 A. M. of the third day.

A number of other repairs belonging to marine engineering have been successfully made—among others, one of a rudder stock five inches in diameter, which was welded with fifty pounds of Thermit and ten pounds of steel punchings. The collar, in this case, had to be entirely removed.

We have also heard lately of a successful weld of a 7″ shaft of a steamer at Columbus, Ga., which was made without any verbal assistance from the Goldschmidt Thermit Company.

An improved method of making such welds has lately been developed at the Essen works. The mold is placed in position after the fracture has been opened out and cleaned, but before it is heated. A suitable coke stove is then placed over the mold, and connected with it is a blower, which drives the fire gases through the coke, around the piece to be welded, and brings not only the latter, but also the mold to a high degree of temperature, thus facilitating the weld and eliminating all possibility of moisture in the mold. This process has been found particularly valuable for the repair of pieces of great diameter.

Most of the defects in castings, however, are naturally detected before these leave the foundries, and it is natural, therefore, that steel foundries were among the first to appreciate the great value of our process for them, as it enabled them to save a large

number of castings. Such defects, although small, entirely destroy the value of a casting. The use of a process like ours, which repairs the defect without in any way diminishing the strength of the casting or interfering with the possibility of machining it, is a practical necessity to steel foundries.

Some important repairs of gray iron castings are worth mentioning. At the Renovo shops of the Pennsylvania Railroad, a hydraulic wheel press was repaired, the part welded having to stand a pressure of sixty tons per square inch The original "strong back" holding the wheel against which the axle was pressed, was not strong enough for the purpose until repaired by Thermit.

Fig. 7. Complete weld of shoe or skeg of Steamship Apache.

The spoke of a fourteen-feet fly-wheel at the works of C. M. Robertson & Co., Montville, Conn., was repaired by Thermit. In the course of moving a segment of the wheel into place, the supporting chain broke, allowing it to fall and crack a spoke, very close to the rim. The entire wheel weighed 11,000 pounds and measured fourteen feet in diameter; the face of the wheel was twenty-five inches in width and two inches of metal in the rim. The segment with the fractured spoke weighed 5500 pounds, and measured seven feet in diameter. The fracture extended diagonally across the spoke. At one point from the inside of the rim to the fracture the distance was one inch.

At another point it was $1\frac{7}{8}''$ away from the inside of the rim. The spoke was elliptical and measured $7 \times 3\frac{1}{2}$ inches.

It was decided to cast around the fracture a collar of thermit steel $4\frac{1}{2}''$ in length and $\frac{3}{4}''$ in thickness. The collar was to fit directly against the rim at the juncture of the spoke and that part. It was calculated that fifty-eight pounds of Thermit and ten pounds of punchings would make the weld. Six half-inch holes had been bored along the break, because if the metal had been cut away to form a distinct space, there would have been some difficulty in keeping the necessary parts in alignment.

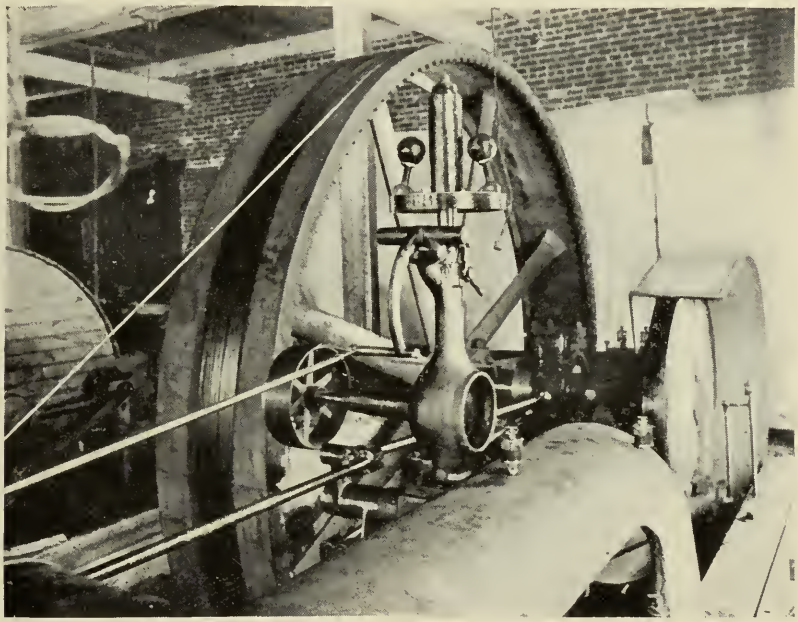


Fig. 8. Welded spoke of flywheel, Montville, Conn.

The two halves of the mold were too large to be put into the boiler furnace or into the ash-pit to dry. A temporary furnace was therefore built, using for the purpose a piece of heavy plate 40″ square, which was supported by brick work construction, standing eight inches from the ground. The supporting wall was closed on the two sides and open on the other. Around the top of the plate, at the outer edges, there were placed three courses of bricks. The two halves of the mold were placed on the plate, and below it a wood fire was started at about noon time. After burning for about two and a-half hours, the mold was covered with charcoal, which was packed all around it. The charcoal was then ignited and the whole covered with an-

other iron plate. The wood fire was kept going until three o'clock the following morning. At 8 o'clock the same morning the fire had died down, but the molds were still hot. This treatment completely burned the mold, resulting in a very quiet action when the steel was poured into it.

The inward curve of the rim prevented the crucible being placed directly over the gate, an extension of the gate was made by taking a sheet metal tube 4″ in diameter and 10½″ long and cutting the ends to an angle of about 45°. It was rammed full of moulding sand, around a ¾″ gate pin. It was afterwards dried in charcoal fire.

A charcoal fire was built about the spoke and kept burning for from two to three hours.

In placing the mold in position, a double length of ordinary twine was taken and around it was rolled moist clay, forming a rope about the thickness of one's little finger, to guard against the metal running out. This was put around the inner edges of the mold boxes, so that when they were clamped together, the clay rope would be squeezed between them, thus effectually sealing all joints. The quantity forced out of the joints by the pressure of clamping afforded a good foundation to build upon when finally luting the outside of the junctions. Not a drop of metal got outside of the mold.

When the mold was fitted, luted, and carefully banked up with damp sand, the gate extension was put in place. Where it joined the mold, damp sand was carefully packed around it. It was held securely by bricks. A trough of bricks and sand was formed at one side of the mold, to conduct away the slag which would be in excess of the capacity of the riser. The charge was then ignited and burned down normally. When the sand and mold were cleared away, there was shown a smooth collar and a good looking weld.

Work with gray iron castings requires more experience in regard to pre-heating and cooling down gradually. More Thermit is necessary to effect the weld in this case, on account of the hard, glassy scale on such castings, which resists fusion, and an addition of ferro-silicon (about 2%) is advisable, to prevent hard spots at the line of junction between the thermit steel and the cast-iron.

Some of the smaller defects have even been repaired without

the use of a crucible, by placing a "pouring cup" over the defect and igniting the Thermit directly in this cup.The cup, of course, must be absolutely dry and must be carefully luted from the outside. Even then there is a risk of the slag not separating entirely from the steel and in that manner preventing a weld. From some experiences, however, it would appear as if this danger were more theoretical than practical. The peculiar shape of the pouring cup no doubt facilitates the displacement of the slag by the heavier weight of the steel.

While in all these welding operations the heat of the slag is either wasted or entirely subsidiary to the heat action of the thermit steel, there is one application of the thermit process which is highly interesting because the manner of proceeding

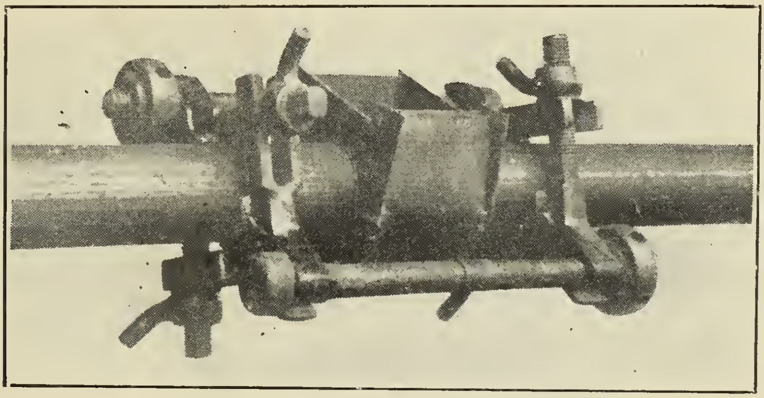


Fig. 9. Welding pipes in horizontal position.

differs entirely from that outlined up to the present. The heat of the thermit steel (unless properly controlled and guided in a mold) will burn through, and destroy any casting. Nevertheless, a method has been developed by which wrought-iron pipes can be welded without banking up the interior. Of course, of the thermit steel were run directly on to the thin walls of a pipe, it would burn through. In this case the joint of a pipe is surrounded by a sheet-iron or cast-iron mold, into which the slag resulting from the reaction is poured first. This slag adheres to the surface—not only of the pipe, but also of the mold, and protects both from being washed away by the thermit steel. The reaction is made to take place in a crucible with a flat bottom and the contents are poured over the lip, so that the slag runs out first and is followed later by the steel. The pipe ends are held in clamps and about a minute and a-half

after the pour the clamps are drawn up and an absolute butt weld is obtained, without any change in the dimensions of the pipe.

Work of this kind was done recently in New York City, for the Manhattan Refrigerating Company. The pipes were laid in the ground, on 14th Street, and are used as service return pipes in the delivery of liquid ammonia—180 pounds pressure—to various cold storage houses along the street. Twenty-nine $1\frac{1}{4}''$ and twenty-seven $2''$ joints were welded. The pipe was welded on the ground, the lengths varying from 40 to 100 feet, then placed into the ditch, cuts made for connections and the final welding done with the pipe in place. On the $2''$ line an expansion bend was placed, while on the $1\frac{1}{4}''$ this was not thought necessary. Both lines were tested out before being thrown into service and no failures showed themselves. It was noted, however, that where the pipe was very thin, blow-holes were in the welded section. A large blister showed itself in a section of the weld. This was noticed at three different times, showing defective pipe. These defects were, of course, cut out, and additional joints made.

If the application of the thermit process for the repair of gray iron castings offers certain difficulties and requires special care, the process, on the other hand, provides gray iron foundries with a ready means of improving their metal, as well as their castings, and avoiding any accidents through dull iron. To mention the latter point first, the reviving of dull iron in the ladle is a simple operation. The Thermit, for this purpose, is placed into cylindrical cans, so constructed as to be easily attached to an iron rod. The can, in this case, contains some ignition powder, as the temperature of liquid cast-iron is not sufficient to start the reaction. The rod with the can at its end is thrust down to the bottom of the ladle, where the reaction commences and permeates the contents of the whole ladle. A small can containing $1\frac{1}{2}$ pounds of Thermit is sufficient to melt 40 pounds of steel borings in an 800 pound ladle, so that one can is also sufficient to revive a ten to twelve hundred pound ladle of dull iron.

There is absolutely nothing explosive in this application, the result being entirely due to the very high temperature created in one place, which communicates itself to the whole metal bath.

In a similar way Thermit can be used to keep open the risers and so do away with the danger of shrinkages just at the point where they are most liable to occur—namely, near the junction of gate and casting. As soon as the liquid metal appears in the channel between the casting and the riser, a paper parcel containing Thermit with some ignition powder at the bottom, is thrown into the riser, and by increasing the temperature of the metal at that point, considerably increases the effectiveness of

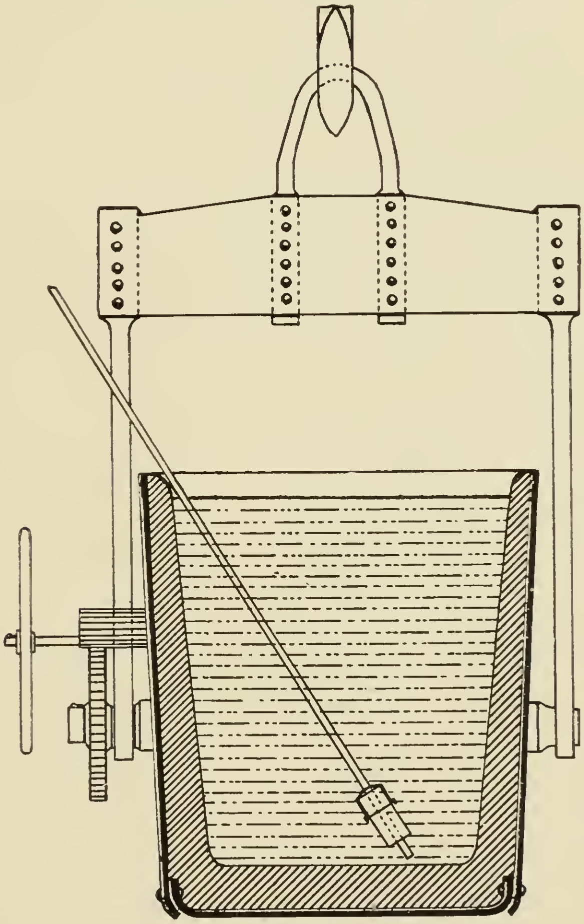


Fig. 10. Introducing Thermit into the ladle.

the riser, and furthermore makes possible a reduction in the size of the riser.

Both applications have found considerable favor with a number of foundries.

Where there is a question of obtaining particularly dense castings, such as are used for cylinders and valves, a special Thermit is recommended, which contains a slight addition of titanium. The Thermit is placed in cans in a manner similar

to the previously describel "semi-steel," or riviving can. The titanium is added to the thermit—not in order to alloy it with the cast-iron, but on account of the affinity of this element and nitrogen. A chemical, automatic poling action is started thereby and the fluidity of the iron is greatly increased, giving the casting greater density and a finer grain. The temperature of the entire ladle is not much increased, as the quantity of Thermit brought to reaction is only from $\frac{1}{16}$ to $\frac{1}{4}$%. Tests of pours made from the same ladle before and after a titanium-thermit reaction, made at the Pennsylvania Malleable Company's Works, McKees Rocks, Pa., will be of interest in this connection.

RIEHLÉ BROS. TESTING MACHINE CO.

Tests on Malleable Iron Bars Cast at Pennsylvania Malleable Co.'s Works, McKees Rocks, Pa.

BEFORE TITANIUM-THERMIT REACTION.

	Dimensions.	Ultimate Strength, Pounds.	Deflection.
No. 1—1	1.000 x .999	4,100	1.00″
1—2	.995 x .999	4,500	.98″
1—3	Lost in anneal.		
2—7	1 060 x .998	4,540	1.28″
2—8	1.012 x 1.006	4,610	1 40″
2—9	1.006 x 1.005	4 500	1 40″
	Average before treatment.	4,450	1 212″

AFTER TITANIUM-THERMIT REACTION.

	Dimensions.	Ultimate Strength, Pounds.	Deflection.
No. 1A— 4	1.011 x 1.010	5,920	1 30″
1A— 5	.999 x 1 000	4 260	1.27″
1A— 6	.989 x .995	4,850	1 55″
2A—10	.995 x .996	4.620	1.47″
2A—11	.998 x .996	4,410	1.37″
2A—12	1.011 x 1.000	4,810	1.44″
	Average after treatment.	4,811	1.60″

In concluding, I venture to think that the practical advantages due to the use of our process will become more and more known, and that by a free discussion of personal experiences, all interested in the process will be encouraged and benefitted.

Improved System of Concrete Piling.

[*Being the Report of the Committee on Science and the Arts on the Invention of Frank Shuman. Sub-Committee, Prof. L. M. Haupt, Chairman; John E. Codman, Louis E. Levy.*]

[No. 2302.]

The Franklin Institute, acting through the Committee on Science and the Arts, investigating the merits of the "Concrete Pile," by Frank Shuman, of Philadelphia, Pa., reports as follows:

The exhibits furnished in this case include the following patents:

No. 733,286, issued July 7, 1903, for Removable Pile for Forming Concrete Piling, containing sixteen claims.

No. 733,287, issued July 7, 1903, for Process of Making Concrete Piles, containing two claims, differing from one another only in the "permitting said concrete to remain without disturbance until it becomes set."

No. 733,288, issued July 7, 1903, for Removable Pile for Forming Concrete Piling, containing twenty-two claims.

No. 733,335, issued July 7, 1903, for Process of forming Openings in the Ground, containing five claims.

No. 733,336, issued July 7, 1903, for Process of Forming Concrete Piles, containing four claims.

No. 733,337, issued July 7, 1903, for Process of Forming Concrete Piles, containing five claims.

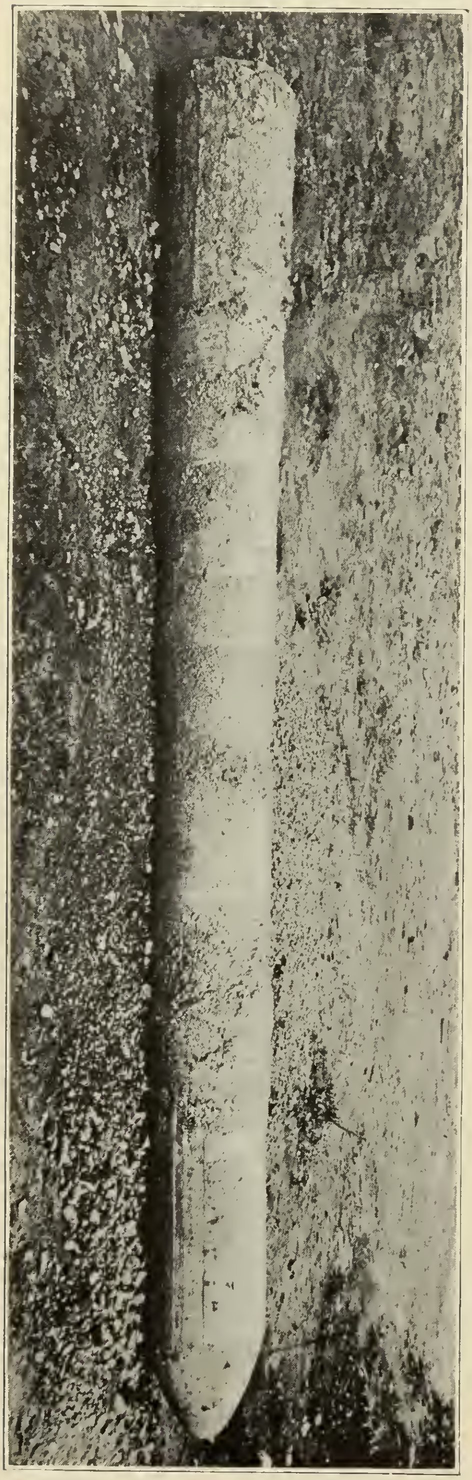
No. 735,680, issued August 4, 1903, for Process of Making Concrete Piles, containing three claims.

No. 739,268, issued September 15, 1903, for Process of Making Concrete Piles, containing eighteen claims.

Also a prospectus issued by the Simplex Concrete Piling Co., describing work actually done at the Washington Barracks, where about 2000 piles were driven and tested to the satisfaction of the U. S. Engineer officers in charge, and several other patents relating to the invention.

From these data and after an interview with the inventor, and after due consideration, your Committee finds that in a general way

The invention consists of two parts, viz.:



Concrete pile 13 feet 2 inches long by 14 inches diam. Dug out intact after test.

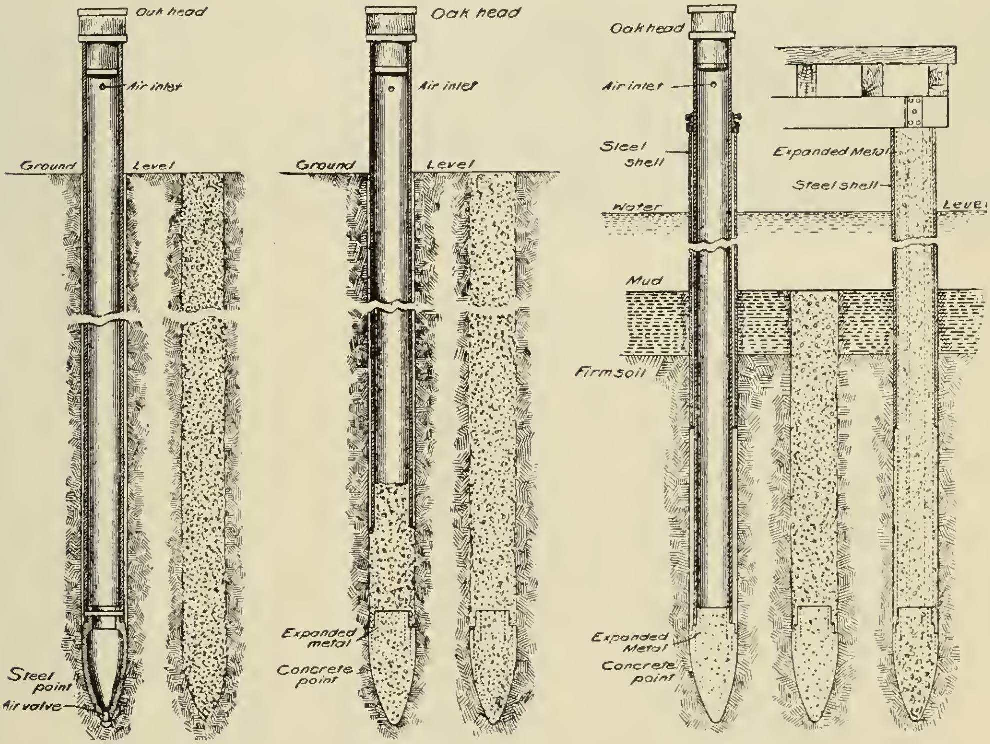
1. A tool for the formation of holes in the ground to contain concrete or other plastic materials, said tool consisting of a suitable hollow shank having a head or point of a larger diameter, and being of an ovidal form, shaped like a shell used in gunnery, riveted to it. The shell is also open at both ends to admit air below the point when the tool is being withdrawn. During driving the hole at the apex is closed by a loose plug, called a valve, which drops out when the form is raised and thus relieves the suction from the vacuum and permits the removal of the pile-former with very small power.

2. The several devices for the filling of the holes with concrete or other material and for holding it in compact position in loose or permeable soil, said device consisting of casings or tubings, which can be removed readily after the concrete has set, and which is designated here as cofferdaming.

The patents therefore cover the process of making the piles and the tool for the formation of the holes or mould for them, and are covered by no less than seventy-five claims,

many of which the Committee believes might be omitted to advantage as being redundant.

STATE OF THE ART.—The use of piles, or piers, whether of earth, stone or other minerals, or of vegetable or metal substances is quite old; the previous perforation of the soil by the driving of a preliminary pile, which is subsequently withdrawn to permit the substitution of other material for the final structure is likewise well known, and hence the merits of this process must consist in securing a better result in less time, or at

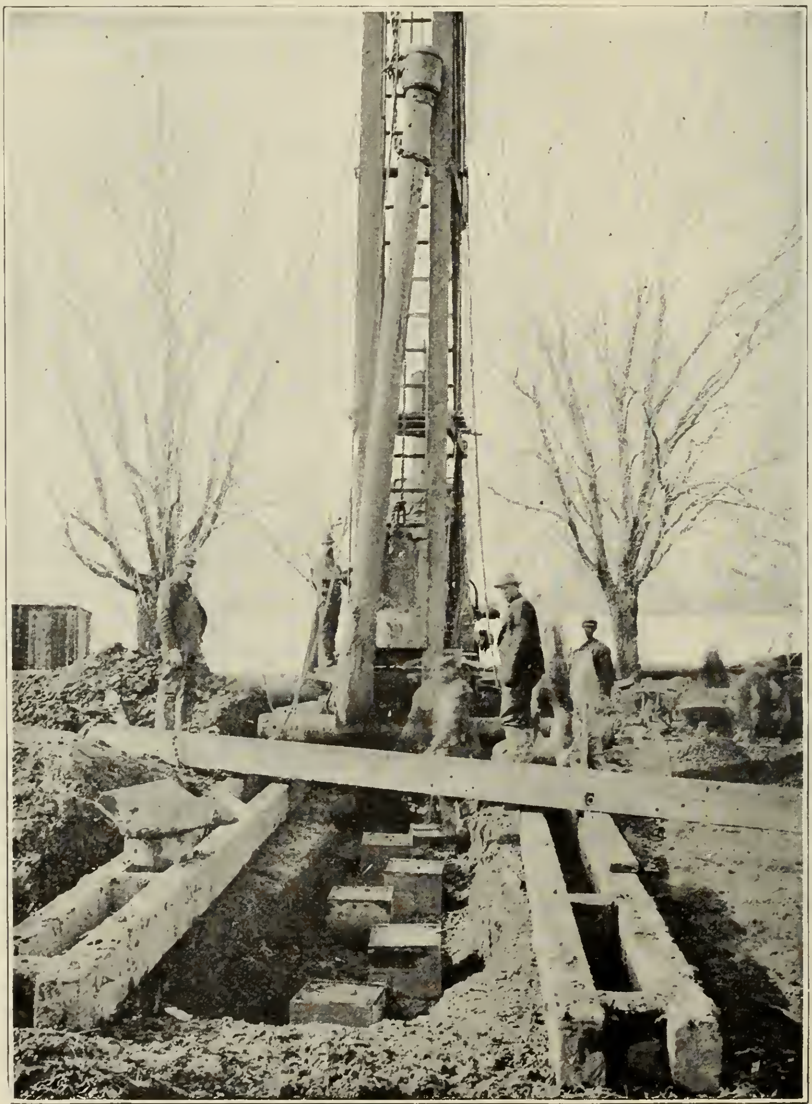


Various Systems of Concrete Piling.

less cost, or both, and thus bringing it within a range of greater economic possibilities.

The specifications state that the invention "Relates to that method of forming piles of concrete or cement, which consists in first driving a preparatory pile into the ground, then withdrawing said preparatory pile, and then filling the opening formed thereby with fluid or plastic concrete or cement, which, when it becomes set will form the permanent pile." "The object of my invention is to so construct the preparatory pile that the same can be driven or withdrawn with the exercise of

Concrete points for long 17-inch diam. piles. Engineers' School, Washington Barracks, D. C.



Preparatory pile removed, leaving hole ready for concrete.

much less power than is required when piles of this class, as heretofore constructed, are used."

This greater ease of operation is accomplished largely through the use of the enlarged head which permits the pile to be driven much more readily and be withdrawn with less difficulty and delay than by existing methods. In some instances it has been found advantageous in practice to substitute a solid, concrete head of larger diameter than the driving rod, instead of the steel shell and to leave the head in the bottom of the hole which is filled up with the concrete as the tube is withdrawn, the tamping being done by a plunger passing down the well.

In view of the manifest economies and advantages of this method of obtaining substantial foundations in all classes of soils and under adverse conditions of weather, the Committee recommends that the inventor be awarded the John Scott Legacy Premium and Medal.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, January 6, 1904.

Attest: WM. H. WAHL, *Secretary.*

AN INDEX TO HYDROGRAPHIC REPORTS.

An index to the hydrographic progress reports of the United States Geological Survey from 1888 to 1903, which has been recently copied by John C. Hoyt and B. D. Wood, will be of interest and service to many persons.

A systematic study of the surface waters of the United States was started by the hydrographic branch of the United States Geographical Survey in 1888. A large part of this work has consisted of measurements of the volume of flow and study of the conditions affecting it. The data collected each year have been published in the Director's annual report, as a bulletin, or as a water-supply and irrigation paper. As the hydrographic work in most localities has continued during several years, the results of the investigations at any one point are scattered through a number of publications, and the only guide to these data has been the individual indexes of the numerous reports. With the growing interest in the commercial development of the hydrographic resources of the country the demand for these data collected by the Geological Survey has rapidly increased, and in order to aid those wishing to use them this index has been prepared. It is published as Water-Supply and Irrigation Paper No. 119, and may be obtained, free of charge, on application to the Director of the United States Geological Survey, Washington, D. C.

MOISTURE AND FURNACE RESULTS.

At the Liége Metallurgical Congress, M. Divary, of Schneider & Co., Creusot, France, gave some interesting information on the occasion of the discussion of Mr. Gayley's dry air process. The observation was made for many years at Creusot that consumption of coke increased and the output of the furnace decreased in summer as compared with winter, and in 1901 records were kept, which in August, 1902, led to a first study. The result of this study was that an economy of 50 to 60 kg. of coke per ton of iron seemed in sight if the furnace was blown with air saturated at 0 degrees Celsius in place of hot and humid air during the summer months.

These researches were continued, and since the difference in consumption of coke observed during one year seemed larger than those justified by calculation it was determined to carry out the system of drying the air by freezing. This was submitted in September, 1903, to several designers of ice machines. After their figures had been received other questions claimed the attention of Schneider & Co., so that the programme was not immediately carried out, but instructions were given to the blast furnace department to observe daily the humidity in the air and the corresponding fuel consumption under conditions guaranteeing accuracy. Three times per day the moisture was observed in the blowing room.

During the year 1904 the charge remained practically the same, the two furnaces, Nos. 2 and 4, running on Basic Bessemer pig. The results are shown in the following table, the first column showing the average amount of moisture per cubic meter of air blown in during the month, the second column the increase in the consumption of coke as compared with that of the dryest month, and the third column showing the average production per furnace for 24 hours:

	Moisture in blast. Gr.	Increase in coke consumption. Kg.	Average furnace product. Tons.
January	6.3	0	90.5
February	6.6	10	88.7
March	7.6	13	87.2
April	7.8	47	81.2
May	10.0	56	78.3
June	11.7	103	75.7
July	13.0	133	70.0
August	12.0	90	76.6
September	9.3	55	90.0
October	8.0	28	86.0
November	7.6	25	86.5
December	7.0	35	88.5

At Creusot the speed of the engines is not lowered in winter and the blast is always heated to the same temperature summer and winter, being an average of 752 degrees Celsius.

The figures agree very closely with those of Mr. Gayley and hold out undoubtedly the results to be obtained from drying blast furnace blast.—*Iron Age.*

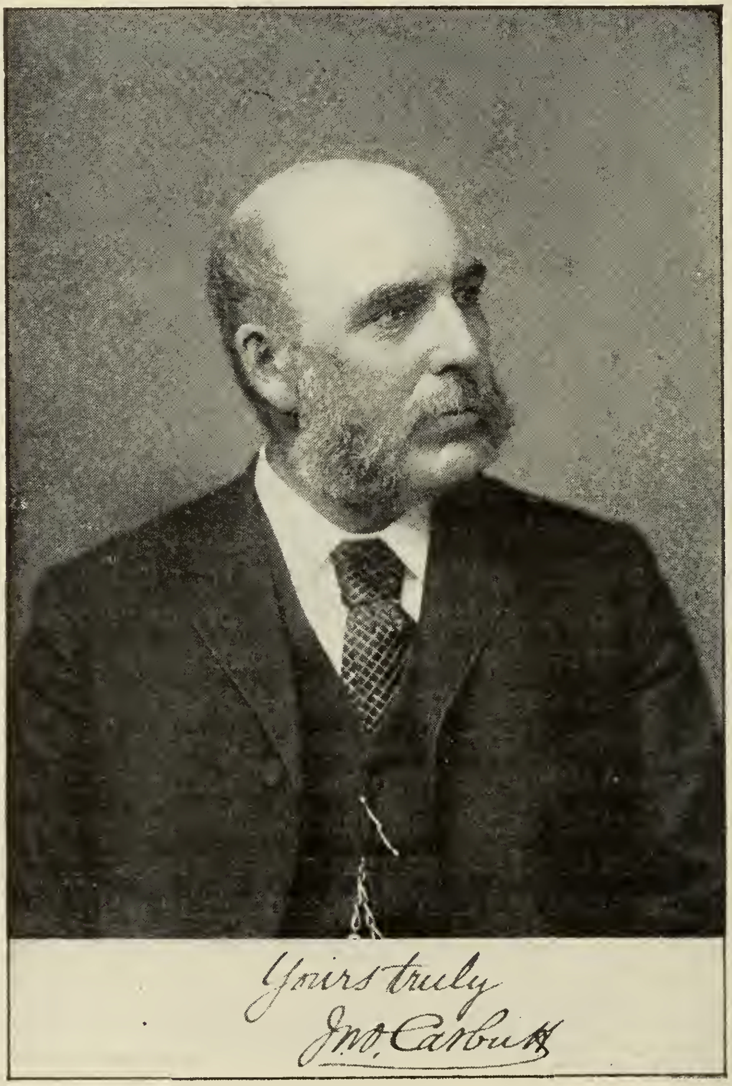
In Memoriam.

John Carbutt.

John Carbutt, who died at his residence, in the Germantown district of Philadelphia, on the 26th of July ultimo, was born at Sheffield, England, December 2d, 1832, and emigrated to this country in 1853. He was one of the early pioneers in that great advance of the photographic art which has followed the introduction of gelatine dry plates. His contributions to this art industry began as early as 1868, when he successfully used gelatine in place of collodio-albumen in the preparation of dry plates in his photographic practice in Chicago. He had previously gained a fruitful experience in the application of dry-plate photography as official photographer of the Canadian Pacific Railway during the building of that road. In 1871 Mr. Carbutt took up the gelatine intaglio printing process, known as the Woodburytype method, and established himself in Philadelphia to work it commercially. In the prosecution of this enterprise he devised numerous and, in some respects, radical modifications of the process to meet the exigencies arising from American climatic conditions and had fairly overcome these difficulties when the development of the less complicated photo-collotype processes led him to abandon the undertaking. Mr. Carbutt then again turned his attention to the preparation of gelatine dry plates and by 1879 he had established a factory for that purpose and put on the market the first American product of this kind.

The Carbutt plates were soon followed by those of other makers, but in certain special classes, notably in plates for lantern slides, they have held a leading place and maintained a widespread reputation. It was through Mr. Carbutt's initiative that the standard size of $3\frac{1}{4}'' \times 4''$ for lantern slides has gradually become prevalent, instead of the varying and smaller sizes formerly in vogue. Mr. Carbutt has also to be credited

with a distinguished part in the development of the chromo-photographic processes, his researches in this direction having led to his introduction of orthochromatic dry plates at a period apparently antedating any other maker. His service in the production of accurate color filters and his contributions to the science of the subject have been notable factors in the ad-



vancement of the art, and in this field generally John Carbutt's work has been of large importance and has left a permanent mark.

Mr. Carbutt was an active member of the Franklin Institute, and for some years a member of the Committee on Science and the Arts. He was the first President of the Photographic Asso-

ciation of America, and did much to effect its successful organization. Also he was an active member of the Photographic Society of Philadelphia. He was an accomplished master of the chemistry of his art and a most industrious worker. A man of genial personality, his efforts had gained him a well-earned competence, but this, unfortunately, proved a less permanent acquisition than his equally well-earned reputation.

LOUIS E. LEVY,
SAMUEL SARTAIN.

THE USE OF COPPER IN DESTROYING TYPHOID ORGANISMS, AND THE EFECTS OF COPPER ON MAN.

In the American Journal of Pharmacy, Prof. Henry Kraemer excellently discusses the effects of water treated with copper on man. His conclusions may be summarized as follows:

1. It is pretty well established that the typhoid organism is disseminated not only through water, but also through air and food, and may retain its vitality for a considerable period of time.

2. Typhoid organisms in water are eliminated by filtration, boiling, and certain biochemical methods. Of the latter, the use of copper, as proposed by Moore and Kellermann, is probably the most efficient and at the same time most practicable.

3. While exceedingly minute quantities of copper in solution are toxic to certain unicellular organisms, as bacteria, it is safe to assume that the higher plants and animals, including man, are unaffected by solutions containing the same or even larger amounts of copper.

4. There being a number of factors which tend to eliminate copper from its solutions, it is hardly likely that there would be any copper in solution by the time the water from a reservior reached the consumer if the treatment of the reservoir were in competent hands.

5. Many plants contain relatively large quantities of copper, and when these are used as food some of the copper is taken up by the animal organism, but there are no records of any ill effects from copper so consumed.—*Scientific Amer. Supl.*

LOST ARTS.

Not as much as we used to, but occasionally even yet, one hears of some wonder accomplished by the ancients which cannot be done now.

Not so many years ago it was quite commonly asserted that modern workmen could not quarry, or, having quarried, could not handle stones as large as the monoliths of Egypt; and the writer has heard a public speaker of note assert that it would be impossible to handle, with modern implements, such large stones as were used in the pyramids, or to join them as perfectly as they were joined there; yet, when occasion arose, larger stones than any of these were quarried in Maine, and some of the larger monoliths themselves were transported, not only to the sea, but across it, and erected in England, France, and America; and there are individuals to-day who might, if they chose, cause the transportation of and erection in this coun-

try of the largest pyramids, or build new ones ten times larger and more durable. Pyramids are not being generally built, nowadays, because they are not in line with the trend of modern ambition; that's all.

It is very doubtful if a "Damascus blade" would stand half as severe usage as a modern band-saw blade, or even as much as the spring of a forty-cent clock; while the ornamentation of those wondrous blades, so far as the mechanical execution is concerned, can be excelled by apprentices and amateurs of to-day.

Of the "lost art" of hardening copper little is heard of late years, though one occasionally hears a wiseling from the wilds wish that he knew how to do it as well as the ancients; and, while it is perhaps regretable that he doesn't, his ignorance is his own fault.

Many arts and devices have been abandoned because new knowledge has made them useless, and time spent in rediscovering them would be worse than wasted. The modern youth would much better spend his time studying the art of his contemporaries than that which is "lost."—*Scientific American.*

ARTIFICIAL CORUNDUM WITH ELECTRIC FURNACE.

In the high temperature produced in the electric furnace it has been shown that all substances can be melted. The oft-encountered statement that lime, magnesia, molydenum, tungsten, and the like, are infusible is therefore incorrect, for not only can all known substances be melted, but they can be volatilized as well. These facts are full of significance and suggestion to the engineer. They not only show him that there are limitations upon the materials which he may use for furnace construction, introducing difficulties where the highest temperatures are to be developed, but it is possible that in the melting and fusion of materials they may undergo such transformation of their physical nature as to endow them with qualities of great value. One of the most successful industrial uses of the electric furnace is the fusion of aluminum oxide in the form of bauxite, resulting in the production of that physical form of the material designated by the trade name "alundum." This is a duplication of nature's process for producing corundum, but the artificial product has marked advantages over the natural material in the purity, cheapness, strength, and toughness, which give it greater value for abrasive purposes.—*Electrical World.*

ENERGY EXPENDITURE IN PRODUCING LIGHT.

In his recent series of lectures on "Flame," at the Royal Institute, Sir James Dewar illustrated in a striking form the large amount of energy expended in the production of a small amount of light. The following figures show how inefficient the various lighting devices now employed are from a scientific point of view: Candle—Percentage of light, 2; non-luminous energy, 98. Oil—Percentage of light, 2; non-luminous energy, 98. Coal gas—Percentage of light, 2; non-luminous energy, 98. Incandescent lamp—Percentage of light, 3; non-luminous energy, 97. Arc lamp—Percentage of light, 10; non-luminous energy, 90. Magnesium lamp—Percentage of light, 15; non-luminous energy, 85. Cuban firefly—Percentage of light, 99; non-luminous energy, 1.

LIST OF DEEP BORINGS IN THE UNITED STATES.

A valuable reference work for the driller is a recent publication of the United States Geological Survey, which is entitled "A Preliminary List of Deep Borings in the United States," compiled by Mr. N. H. Darton, chief of the Western Section of Hydrology.

The first preliminary list of deep borings in the United States was issued as water-supply papers Nos. 57 and 61. The present publication includes all of the wells listed in these two papers, together with many additional borings, mostly of recent date. Messrs. M. L. Fuller and A. C. Veatch of the Eastern Section of Hydrology, and other geologists of the Survey, have contributed many new data. Descriptions of borings published in reports issued since 1901 have been incorporated as far as practicable. All the entries are by States and countries.

The wells and borings reported in the paper are all more than 400 feet in depth. The information concerning them has been obtained partly from replies to circular letters sent to all parts of the United States and partly from geological reports and other published sources. Owing to the difficulty of obtaining replies to the circulars, to lack of knowledge on the part of correspondents, and to the incompleteness of published records, doubtless there are borings which have not been reported. In regions of oil and gas wells, where borings are numerous, all the individual wells can not be listed, but representative wells are given. References to logs or records of the wells or extended descriptions of them are given in footnotes and following the list of wells in each State is a list of the principal publications relating to deep borings in that State.

This publication is listed as Water-Supply and Irrigation Paper No. 149. It may be obtained, free of charge, on application to the Director of the United States Geological Survey, Washington, D. C.

SUPPRESSING THE SMOKE.

One suburb of Cleveland containing large steel works has been redeemed in the most remarkable manner by the introduction of automatic stokers, so that there is now a place for human beings to live, where formerly all was soot and blackness. The president of a manufacturing company using four stokers reports that he is not only paying from fifty to seventy-five cents less per ton for his fuel, but is burning six tons less per day than formerly, and at the same time getting better satisfaction in the maintaining of a uniform steam pressure. It is undoubtedly true that the agents of smoke-abating devices of all sorts have been extravagant in their claims and that they have damaged their own business by such claims, but this is a mistake not confined to the furnace business. A conservative claim of from 10 to 20 per cent saving, depending upon how smoky the furnace has been, can usually be substantiated by a comparison of the coal bills before and after introducing stokers, without resorting to expert tests.—*Scientific American Supplement.*

ELECTRIC LOCOMOTIVES.

The New York Central Railroad has made a lengthy series of tests of an experimental electric locomotive, designed for handling the express traffic within a radius of 35 miles of the New York treminal station. These tests have been carried out on a six-mile stretch of track on the main line of the company's system, west of Schenectady, and they have now been continued steadily for such a long period of time, that the engine may be said to have experienced practically every conceivable condition of weather, load, and track. The data gathered in this way are so eminently satisfactory, that the company has placed orders for electrical equipments, which are said to aggregate over $6,000,000 in value. The order includes thirty-five electric locomotives for the through express service, and 175 cars, which are to be used in the suburban service. Each of these engines will weigh about ninety-five tons and will develop normally 2,200 horse-power, although this amount can be exceeded when it is necessary. They will be carried on eight 44-inch driving wheels, all coupled. Although the draw-bar pull considerably exceeds that of the most powerful steam express locomotives of the day, the concentrated load on the drivers will be considerably less than that on steam locomotives Each engine will be able to haul at schedule speed a train of about twelve cars, equivalent to a load of about 500 tons. The electric locomotives will be coupled to the main-line incoming texpress trains at Croton, where there will be a running shed and shop conveniences for both the steam and electric locomotives. The expresses will be run into and brought out from New York City entirely by electric power. The same conditions will prevail at White Plains, twenty-five miles out from New York City on the Harlem Division, where the steam locomotives will be uncoupled and the electric locomotives will take their place. It is expected that this equipment will be ready for work within the next twelve months, by which time sufficient progress will have been made with the change of tracks to admit of a partial use of the electrical service.—*Scientific American.*

RADIUM AND SPONTANEOUS GENERATION.

A special cable dispatch of June 24 to the New York *Evening Post* says: "The greatest interest has been excited by the discovery of Prof. John B. Burke, of the Cavendish laboratory, which may be summarized thus: After years of negative experimentation on the phospherescence of cyanogen, which Pfluger declared to contain the element of life, Mr. Burke resolved to test it with radium, and placed it in the test tube with sterilized bouillon. After a couple of days cultures were obtained of atoms which subdivide on reaching a certain size. Placed upon fresh portions of sterilized bouillon, these growths continue to grow slightly, thus showing that the influence of the raduim is only initiatory. Prof. Simms Woodhead pronounced them neither bacteria nor crystals; but they present many appearances of vitality and seem to indicate the possibility of spontaneous generation. * * * * Leading men of science maintain an attitude of reserve as to the vitality of Professor Burke's radiobes."

WIRELESS TELEGRAPHY.

The Government and Wireless.—A recent special dispatch to the New York *Tribune* says: "The wireless experts of the Government are applying themselves with energy to the problem of getting rid of the influences which are destined to interfere with that form of communication in time of war, or at least to prevent secret exchange of messages. There have been many assurances that this would be possible by means of special devices used, but it is found that the wireless stations along the coast obtain many messages, in whole or part, which are not intended for them. Thus, at the Washington Navy Yard recently there were received messages evidently being exchanged between ships in distant Southern waters. There is nothing to account for this irregularity in the action of the messages; so much depends upon the wave influences. At the same time, it is realized that something must be done toward the regulation of the wireless communication. Much may be acomplished by governmental control, but this may not be possible, now that the wireless companies are fully organized and have sold stock to people who may feel that their interests would not be helped by legislation along the lines suggested by the special joint board of which Rear Admiral Evans was the senior member. There is also much to be obtained from an international discussion of the subject, but this appears to be out of the question during the war between Russia and Japan and until the British and Italian governments adjust their relations with the Marconi people."

STANDARDIZING ANALYSIS METHODS.

H. E. Diller, Secretary of the Metallurgical Section of the Association, made a report for the past year. The principal work undertaken was the standardizing of methods of analyzing cast iron. The committee has agreed on the method for determining silicon and had almost ready a method for determining total carbon. The committee's method for the determination of silicon in pig iron and cast iron as follows:

"Weigh 1 gram of sample, add 30 c. cm. nitric acid (1.13 specific gravity); then 5 c. cm. sulphuric acid (conc.) Evaporate on hot plate until all fumes are driven off. Take up in water and boil until all ferrous sulphate is dissolved. Filter on an ashless filer, with or without suction pump, using a cone. Wash once with hot water, once with hydrochloric acid. and three or four times with hot water. Ignite, weigh and evaporate with a few drops of sulphuric acid and 4 or 5 c. cm. of hydrofluoric acid. Ignite slowly and weigh. Multiply the difference in weight by 0.4702."

The committee presented this method as one that sacrificed shortness to insure accuracy, and that left little to the judgment of the chemist. While it was recognized that it is almost impossible to get chemists to use a standard method in their daily work, the one proposed would serve as a check method in case of dispute between laboratories or between buyer and seller.—*Foundrymen's Assoc'n.*

Book Notices.

PUBLICATIONS RECEIVED.

Bulletin of the University of Wisconsin, No. 121, College of Engineering. Course in Chemical Engineering, Madison, 1905. 19 pages, 12mo. (A new course which has recently been adopted by the university.)

Inauguration du Percement du Simplon. Exposition de Milan, 1906. Programme de la Section de la Prévoyance Internationale. 6 pages. 8vo.

Niles Electric Traveling Hoists and Trolleys. Niles-Bement-Pond Company, New York, 1905. 23 pages, illustrations, obl. 8vo.

The Trump Concrete Measuring and Mixing Machine. Booklet No. 5. Philadelphia Link-Belt Engineering Company, 1905. 29 pages, illustrations, 8vo.

The Trump Measuring and Mixing Machine for Sand-Brick and Artificial Stone Manufacture. Booklet No. 56. Philadelphia, The Link-Belt Engineering Company, 1905. 16 pages, illustrated, 8vo.

The Weather Forces of the Planetary Atmospheres, by C. Merti. Niden, Switzerland. Printed by E. Weber, 1905. 21 pages, illustrations, 8vo.

Missouri Bureau of Geology and Mines, E. R. Buckley, Ph. D., Director and State Geologist, Vol. 3, 2nd Series. The Geology of Moniteau County, by F. B. Van Horn, with an introduction by E. R. Buckley. Jefferson City, Hugh Stephens Printing Co. n.d. 104 pages, illustrations, plates, maps, 4to.

U. S. Geological Surveys, Charles D. Walcott, Director. Mineral products of the United States, calendar years 1895 to 1904. Sheet 24x31½ inches. Washington, August, 1905.

United States War Department. Annual Reports for the fiscal year ended June 30, 1904. Vols. 11, 12, 13. Report of the Philippine Commission, parts 1, 2, 3; vol. 14, Acts of the Philippine Commission (Nos. 950-1251, inclusive) and Public Resolutions, etc., from September 24, 1900, to August 31st, 1904. 4 vols., illustrations, plates, maps. 8vo. Washington, Government Printing Office, 1904-5.

Twenty-first Annual Report of the United States Civil Service Commission for the year ended June 30, 1904. January 4, 1905. Washington, Government Printing Office, 1905. 366 pages, 8vo.

Origin of Planets and Cause and Mode of Production of Terrene Phenomena. Geography of pleistocene earth, by J. I. Lengsfield. Vicksburg, Mississippi, 1897. 6 pages, plate, 8vo.

Explanation of Cause of Weight, by J. I. Langsfield. Vicksburg, Mississippi, 1905. 8 pages, plate, 8vo.

Procêdê pour déterminer la pureté de l'huile de coprah. Par M. Ernst Milliau. 1905. 4 pages, 4to.

Manufacturing Chemists' Association of the United States. Standard Tables for Aqua Ammonia, Hydrochloric Acid, Nitric Acid and Sulphuric Acid. (Folded sheets.) New York, 1903 and 1904.

The Principal Professional Papers of Dr. J. A. L. Waddell, Civil Engineer. Edited by John Lyle Harrington, Civil Engineer. First Edition. Virgil H. Hewes, 245 West 107th Street, New York. 1905. (Price, $5.00, postpaid.)

The title leaves the reader under the impression that the book before us is the work of one author, whereas it is really the work of many, including a formidable array of the giants of the profession; for the editor has included much, if not all, of the discussion which followed the more important of the papers selected, and has himself given us, not only a preface and a biographical sketch of the author, but also notes introductory to most of the papers, and editorial comments following them.

The words "First Edition," in the title page, leave room for the inclusion of further papers in later editions; and that such papers are to be expected may be inferred from the author's portrait, which forms the frontispiece, and which, like the biographical sketch, shows him to be a man with decades of good work ahead of him.

Most of the papers here printed have long been well known to the profession; but the editor, having found them exceedingly helpful to him, has here collated them in convenient form.

Except the first two papers, "Railroad Drainage" and "Notes on Railroading," which appeared in 1878 and 1879, respectively, the papers here collated were written during the score of years from 1885 to 1904, inclusive.

Among the subjects treated, three stand out pre-eminently, viz.: (1) the education of civil engineers, (2) the design and construction of bridges, and (3) elevated railways. These subjects, together, occupy more than eighty per cent. of the volume.

The author's views on the education of the civil engineer are embodied chiefly in two important papers, viz.: IV, Civil Engineering Education, published in Engineering News in 1886, and XXI, Higher Education for Civil Engineers, a paper read before the Engineering Society of the University of Nebraska, in 1904.

From the use of the hackneyed term, "higher education," it is not to be inferred that the author advocates what is so generally understood under that term, viz.: a high degree of superficial and chiefly ornamental finish; but, on the contrary, a broadening and deepening of the foundations of civil engineering education, with such increase in the dimensions of the superstructure as this strengthening of the foundations will warrant.

The principal papers on the design and construction of bridges are—

VIII. General Specifications for Highway Bridges of Iron and Steel, a paper read before the Engineers' Club of Kansas City, in 1888, and published in the Transactions of the Association of Engineering Societies, Vol. VII, No. 11, November, 1888.

IX. Some Disputed Points in Railway Bridge Designing, Transactions American Society of Civil Engineers, Vol. XXVI, February and March, 1892.

X. The Compromise Standard System of Live Loads for Railway Bridges and the equivalents for same, 1893.

In the general specifications for highway bridges, the author paid his respects to highway bridge builders (whom he dubbed "highwaymen,") and

expressed a doubt as to "whether it be possible to reach county commissioners and produce any impression upon them."

A lively discussion was brought out by the other two papers named, and notably by their dominant feature, viz.: the plea for the abandonment of the use of concentrated wheel loads in the determination of stresses, and the substitution, for them, of an equivalent uniform load.

A glance over recent bridge specifications, both by bridge builders and by railroad campanies, bears out the editor's statement on page 458 "that the wheel load method of computing stresses in railway bridges remains in very general use to-day," a fact which the editor deplores as "not at all complimentary to the railway and the bridge engineers of the country," and as attributable "chiefly to their failure to understand the degree of accuracy obtainable by the Equivalent Uniform Load Method."

The discussion brought out considerable difference of opinion as to the amount of labor involved in the determination of stresses by means of concentrated wheel loads, and, consequently, as to the desirability of replacing that method by a simpler one.

In papers XIII and XX, the author describes respectively his well-known and unique Halstead Street lift bridge at Chicago, and his emergency work in replacing a span of the Kansas City Flow Line bridge, carried away by a flood in 1893. This mishap cut off the city's water supply and thus placed the city in "constant and imminent danger from fire and pestilence."

Paper XIV, Elevated Railroads, with the discussion which follows it, may be regarded as a well-illustrated treatise of nearly 200 pages, by authors foremost in this branch of the profession.

The author, as consulting engineer to the Northwestern and Lake Street Elevated Railroads, Chicago, made "an elaborate investigation concerning the best way to design, manufacture and build such structures;" and his paper discusses in detail the materials to be employed, the dimensions and weights of rolling stock, the most advantageous length of span, the use of braced towers *versus* solitary columns, the anchorage of columns, the use of plate girders or of trusses, forms of rails, bracing and superelevation on curves, etc., etc., and submits, describes and illustrates thirteen distinct designs for such structures.

The editor's bioraphical sketch of the author easily explains the preponderance, already noted, of engineering education and of bridge design and construction, in the papers here presented; the author having acted as assistant professor of two branches in the Rensselaer Polytechnic Institute, and from 1882-86 as Professor of Civil Engineering in the Imperial University of Tokio; while, since that time, his professional activity has been very largely in the field of bridge engineering.

The author's deep interest in matters Japanese is shown in paper III, an address delivered before the members of the Kogoku Kyokai, in 1886, at which early day he felt called upon to criticise rather unsparingly the condition of many of the engineering features of the country, and even remarked that, at that time, "well-filled bookshelves" would have formed an innovation in the furnishing of their homes. Still worse, we learn, from both

author and editor, that "Japan's business methods and her ideas of business integrity are still quite oriental, to her detriment." Judging from recent expressions by the author, the writer is led to suppose that the Asiatic Ethiopians, under consideration, may, to some extent, have since changed the skins which they wore twenty years ago.

The author's writings have ever betrayed, by their virility, his inheritance of the proverbial combativeness of his Hibernian paternal ancestors. Hence it is not surprising to find even some of the earlier papers so far in advance of their time as to be well up-to-date to-day, even though some of them may now be found abreast of (rather than in line with) our present notions. In those few cases where the procession has moved on beyond them, the editor's comments will be found to make up, in great part, for the deficiency.

The "papers" constitute a good story, well told, and they leave the profession indebted both to the author and to editor. J. C. T., Jr.

Hypochlorite und elektrische Bleiche. Theoretischer Theil. Theorie der elektrochnische Darstellung von Bleichlauge. Von Dr. Emil Abel. Chemiker der Siemens & Halske A.-G. Wien. Mit 10 Figuren und 10 Tabellen im Text. Halle a S. Verlag von Wilhelm Knapp. 1905. (Price, 4.50 marks.)

This volume forms the seventeenth of the invaluable series of monographs upon applied electricity issued from the Knapp press. Like its predecessors, it is a thoroughly well presented exposition of the art to which it relates. W.

Select Methods in Food Analysis. By Henry Leffmann, A. M., M. D., and Wm. Beam, A. M., M. D., F. I. C. (Second edition, revised and enlarged, with one plate and fifty-four other illustrations. 8 vo. pp. vi + 396.) Philada.: P. Blakiston's Son & Co. 1905. (Price, $2.50 net.)

This second edition of a work that has met with the cordial approbation of analysts in this field, exhibits many additions which serve to make it an up-to-date hand-book. The principal additions relate to polarimetry, destillation and extractions; new processes for the detection of colors, such as substitutes for fruit and egg colors; improvements in the detection of formaldehyde, abrastol and saccharin; rapid methods for the examination of vanilla and lemon extracts, and for the determination of fat in condensed milk and cereal foods; determination of boric acid in fruit juices; analytic data regarding fruit juices, jams and jellies; detection of palm oil in oleomargarin, and numerous minor modifications of tests and processes. W.

Practical Laws and Data on the Condensation of Steam in Covered and Bare Pipes, to which is added a translation of Péclet's "Theory and Experiments on the Transmission of Heat Through Insulating Materials." By Charles P. Paulding, M. E. 8-vo. pp 102. New York: D. Van Norhand Co. 1904. (Price, $2.00 net.)

The author sets forth in this volume the application of Péclet's method to the estimation of the loss of heat from steam pipes and boilers. The accompanying translation of Peclet's work will be welcomed by heating and refrigerating engineers. W.

Sections.

(*Abstracts of Stated Meetings.*)

Section of Photography and Microscopy.—The thirty-fourth stated meeting of the Section was held Thursday, October 26th, 8 P. M. Dr. Henry Leffmann in the chair.

Present, 39 members and visitors.

Mr. C. C. Balderson presented the first communication of the evening—a description of and demonstration with a new form of reflecting lantern, devised by Messrs. Williams, Brown & Earle, of Philadelphia. The speaker showed the possibilities of the apparatus by projecting on a screen a number of illustrations from books and other opaque objects. The subject was discussed by Drs. Leffmann and Goldsmith and the speaker.

Dr. Henry Leffmann followed with a paper entitled, "The Need of Legal Restrictions on the Publication of Photographs."

The speaker referred especially to the abuses now so evident in connecion with postal cards and moving-picture shows, and urged the need of legislation to prevent the undesired publication of portraits of private persons. The meeting then adjourned.

M. I. Wilbert, *Secretary.*

Chemical Section.—Stated meeting, held Thursday, November 9, 8. P. M. Dr. R. H. Bradbury in the chair.

Present, seventeen members and visitors.

The President introduced Dr. Edward Keller, of Baltimore, Md., who presented a paper on New Laboratory Appliances.

The subject was discussed by Dr. Edward Goldsmith, Dr. W. J. Williams, Dr. R. H. Bradburv and Mr. C. J. Reed.

The thanks of the Section were voted to the speaker of the evening and the session was adjourned.

Edward A. Partridge, *Secretary.*

Franklin Institute.

(*Proceedings of the Stated Meeting held Wednesday, November 15, 1905.*)

Hall of the Institute,
Philadelphia, November 15, 1905.

President John Birkinbine in the chair.

Present sixty-three members.

Additions to membership since last report, three.

The Chairman introduced Mr. John C. Trautwine, Jr., member of the Institute, who read an interesting paper on The First Water-works of Philadelphia. The speaker's address was profusely illustrated with the aid of lantern pictures showing many of the engineering details of this now historic plant.

After some discussion of the subject, the meeting passed a vote of thanks to the speakers of the evening and was adjourned.

WM. H. WAHL, *Secretary.*

Committee on Science and the Arts.

(Abstract of Proceedings of the Stated Meeting held Wednesday, November 1, 1905.)

DR. EDWARD GOLDSMITH in the chair.

The following reports were adopted:

(No. 2322.) *Pressed-Steel Shaft Hangers.* The Standard Pressed Steel Co., Philadelphia.

ABSTRACT: These hangers are made from sheet steel pressed into shape and the parts riveted together, making a hanger which is much lighter and stronger than hangers made from cast-iron.

Excepting the box, bolts, rivets and adjusting screws, the hangers are made entirely from the best open-hearth steel, pressed to shape.

The legs, their entire length, are strongly ribbed and flanged. These legs are securely tied together at three points: at the feet, by a corrugated steel tie-plate; in the middle by a strongly corrugated and riveted brace; and at the extreme ends, by a pressed steel yoke, which caps them, removing the last chance of their spreading.

The yoke is held in place by two bolts, which fit accurately in drilled holes. As these run through the legs, not into them, it is obvious that the force applied cannot strip the thread or make the bolts come loose. Thus, the frame is very rigid, is well able to carry the load for which it is intended, and yet weighs only one-half as much as any other shaft-hanger of the same size.

Instead of having to remove the yoke from the hanger when the shaft or box is to be fitted, it only requires the removal of one of the bolts, when the other acts as the part of a hinge, and allows the cap to swing out of the way. When the box has been placed in position it is but a moment's work to swing the yoke back, insert the bolt, and the hanger is ready for use.

Another advantage is the fact that the feet of the hanger are pressed to shape in dies and are therefore absolutely true. This assures a secure base for the hanger, a firm hold upon the joist, and removes the least chance of its shifting out of position.

The report of the Committee calls attention to the fact that these products represent another profitable use to which pressed steel may be applied. The award of the John Scott Legacy Premium and Medal is recommended to the inventor, Mr. Howard P. Hallowell. (*Sub-Committee,* Anson W. Allen, Chairman; Robert Job, Chas. Day, Thomas P. Conard.)

(No. 2368.) *System of Flame Regulation.* Byron E. Eldred, Brookline, Mass.

ABSTRACT: This invention consists of a method of regulating the temperature, volume and duration of flames produced in the combustion of fuel, and the application of this method to various industrial processes,

such as the calcining of lime and cement-forming material, the roasting of sulphide ores, etc.

The essential feature of this invention is the use on an "artificial accellerated draft, composed of air and a neutral gaseous diluent," in place of the current of ordinary air with which it is customary to supply fires. The diluent consists of gases like nitrogen and carbonic acid, which are neither combustible nor supporters of combustion, and which may be derived from the combustion of fuel or the burning of lime rock.

By adding a suitable proportion of this diluent—say one volume to three or four volumes of air—and then forcing the mixture by a suitable means, such as a fan-blower, through the fire, a practically perfect combustion of the fuel is obtained, while the liberation of the heat is so retarded as to furnish a flame of great length and volume. In this way, the overheating of those parts of the furnace and the charge which are near the fuel is prevented, and the heat is liberated where it is needed. The principal application of this idea is in the calcining of lime and cement-forming material. This is covered by U. S. Letters-patent No. 692,257 February 4, 1902.

In the burning of lime by the continuous process with external fires, wood, or a mixture of wood and soft coal is generally used as the fuel. In the process as modified by Eldred, coal, even of very inferior grade, may be used instead. It is claimed that the flame in this case can be so regulated as to insure a very uniform burning of the rock and the prevention of overburning any part of it.

* * * The actual heat of the combustion of fuel cannot be increased by the introduction of a neutral diluent, the effect of the latter being simply to distribute the heat of the combustion over a larger space, permitting a better utilization of the heat, and the effective use of inferior grades of fuel.

Recognizing that the Eldred method has proved itself satisfactory and economical in its application to lime-burning, and believing that it will be applied advantageously in other directions, the award of the John Scott Legacy Premium and Medal is recommended to the inventor. (*Sub-Committee*, Harry F. Keller, Chairman; Chas. E. Ronaldson, Thos. P. Conard, G. H. Clamer.)

The following report passed first reading:

(No. 2372.) *Physical Diagnostic and Surgical Instruments.* Henry Emerson Wetherill, Philadelphia.

Mr. Louis E. Levy, chairman of a special committee appointed for the purpose, presented a memoir of the late John Carbutt, which was accepted and ordered referred to the Committee on Publications.

Wm. H. Wahl, *Secretary.*